THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

MID-OCTOBER 1909

MEETINGS OF THE SOCIETY: ST. LOUIS, OCTOBER 16; BOSTON, OCTOBER 20; NEW YORK, NOVEMBER 9; ANNUAL MEETING, NEW YORK, DECEMBER 7-10

MID-OCTOBER 1909 VOL. 31 No. 9

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OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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As announced in the October number of The Journal meetings are to be held in St. Louis on October 16 and in Boston on October 20. Professor Carpenter will again present his paper on high-pressure pumps at the former meeting, and at the latter will be given a paper on Reinforced Concrete Beams by Prof. Gaetano Lanza and Lawrence S. Smith. This paper is published in the current number of The Journal.

The next New York monthly meeting will be on Tuesday evening, November 9 when the paper on Reinforced Concrete Beams will again be presented. Prof. Walter Rautenstrauch of Columbia University will also present a paper, published in this number of The Journal, upon The Design of Curved Machine Members under Eccentric Load. These two papers with their discussion will cover thoroughly the subject of stresses in two important elements entering into structural work and machine members. The subject of reinforced concrete is of interest to a large proportion of the membership of the Society and the paper by Professor Rautenstrauch will be discussed by engineers engaged in machine design.

On Friday afternoon, October 8, was held a joint meeting of all the Standing Committees of the Society to consider the budget for the new fiscal year.

On Tuesday afternoon, October 12, the first meeting of the Council for 1909–1910 was held in the rooms of the Society, and in the evening the first New York meeting of the Society, with a paper by Prof. R. C. Carpenter upon The Pumps of the High-pressure Fire System of New York City.

ANNUAL MEETING

The annual meeting of The American Society of Mechanical Engineers will be held in the Engineering Societies' Building, New York, December 7 to 10. Papers are to be presented on electric driving, discussing the economic as well as the technical phases of the subject; upon apparatus for the measurement of flow of air, steam and water; and various miscellaneous subjects, including tests of lubricating oils and steam turbine nozzles, governing rolling mill engines, the use of moist fuels, boiler joints, pump valves, cast-iron test bars, etc. Full announcement will appear later.

RAILROAD TRANSPORTATION NOTICE

For members and guests attending the Annual Meeting in New York, December 7–10, 1909, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 3 and 9 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through-tickets, he will tell you the nearest station where they can be obtained, Buy a local ticket to that point and there get your certificate and through-ticket.

c On arrival, present your certificate to S. Edgar Whitaker at headquarters, with 25 cents for validation. A certificate cannot be validated after December 10.

d An agent of the Trunk Line Association will validate certificates December 8, 9 and 10. No refund will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for certificate, and to turn it in at headquarters. Even though you may not use it this will help others to secure the reduced rate.

f If certificate is validated, a return ticket to destination can be purchased, up to December 14, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlotteville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

New England Passenger Association, except via Bangor and Aroostook R. R., Rutland R. R., N. Y. O. & W. R. R., Eastern Steamship Co. and Metropolitan Steamship Co.

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri; north of a line through Kansas, Jefferson City and St. Louis, Illinois; north of a line from Chicago through Peoria to Keokuk.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

JOINT COMMITTEE MEETING ON A STANDARD TONNAGE BASIS FOR REFRIGERATION

In November 1908 the Council of The American Society of Mechanical Engineers approved a recommendation that the Committee on a Standard Tonnage Basis for Refrigeration, already appointed, pre-

pare a joint report with a committee to be appointed by the American Society of Refrigerating Engineers on the same subject. The members of the committee appointed by The American Society of Mechanical Engineers are: Philip DeC. Ball, D. S. Jacobus, E. F. Miller, A. P. Trautwein and G. T. Voorhees. The committee appointed by the American Society of Refrigerating Engineers are: Louis Block, F. E. Matthews, W. E. Parsons, Thomas Shipley and John E. Starr, *Chairman.*

A meeting of the joint committee was not held for some little time as it was considered advisable to wait for the printed reports showing what had been done on the subject of recommending standard units at the meeting of the International Congress of Refrigerating Industries, held in Paris in October 1908. The first meeting of the joint committee was held at the rooms of The American Society of Mechanical Engineers September 29, 1909. There were present three members of the committee appointed by The American Society of Mechanical Engineers, and four members of the committee appointed by the American Society of Refrigerating Engineers. Dr. Jacobus was made chairman of the joint committee, and F. E. Matthews, Secretary.

The committee arranged to send out a circular letter to parties specially interested in refrigeration, requesting coöperation and inviting criticism on certain units proposed for measuring the cooling effect or refrigeration, and on a standard set of conditions for determining the tonnage capacity. Anyone interested will be gladly furnished with copies of this letter on communicating with F. E. Matthews, secretary of the joint committee, 29 West 39th Street, New York. A request was made that replies be sent before October 12, that the matter may be brought up at the meeting of the American Society of Refrigerating Engineers in Chicago October 18, but the committee will be glad to hear from anyone interested after that date.

DINNER TO SIR WILLIAM H. WHITE

On Monday evening, October 4, the President, past-presidents and members of the Council of The American Society of Mechanical Engineers gave a complimentary dinner to Sir William H. White, Honorary Member, Am.Soc.M.E. William Barclay Parsons, a personal friend of the guest of honor, and H. deB. Parsons, who represented the Council at the conference with the Institution of Mechanical

Engineers the past summer, in connection with the proposed joint meeting next year, were also present.

Sir William H. White is one of the most able naval architects and designers, having been director of naval construction and assistant controller of the royal navy (Great Britain) from 1885 to 1902, during which period he was the responsible designer for all the British warships. His most recent design was the Mauretania. In responding to the toast of the Institution of Mechanical Engineers, of which he is a past-president, he spoke of the cordial regard in which the institution holds the American society and of the delight with which they look forward to the joint meeting next year. The two associations are working hand in hand for the advancement of the interests of the mechanical engineering profession in both countries.

William Barclay Parsons, member of the Institution of Civil Engineers and of the American Society of Civil Engineers, in responding to a toast to the latter organization, said that he looked forward to the time when the engineering profession would represent more solidarity and that he believed, although there is a field for the specialist, that the profession as such should seek all possible opportunities for coöperation. An informal discussion then followed of the proper standards and qualifications for membership in engineering societies, and of engineering education, a subject to which Sir William White has contributed much time and attention as chairman of the Committee on Education and Training of Engineers appointed by the Institution of Civil Engineers. The report which was presented by this committee is the most exhaustive statement of the subject ever made.

Those present at the dinner were: President, Jesse M. Smith; Past-presidents, F. W. Taylor, Charles Wallace Hunt, F. R. Hutton and Ambrose Swasey; Members of the Council, R. C. Carpenter, F. M. Whyte, George M. Basford, Henry G. Stott, H. L. Gantt, William H. Wiley; Secretary, Calvin W. Rice; and the guests of the evening.

THE ENGINEERING SOCIETIES BUILDING FOR 1909

The following statistics of the engineering societies in the Engineering Building compiled by the Secretary of the United Engineering Society, Prof. F. R. Hutton, Past-President and Honorary Secretary, Am. Soc.M.E., are taken from the Proceedings of the American Institute of Electrical Engineers.

MEMBERSHIP OF SOCIETIES

Society	Membership
American Institute of Mining Engineers	4,300
The American Society of Mechanical Engineers	3,800
American Institute of Electrical Engineers	6,400
N. Y. Electrical Society	950
American Gas Institute	1,300
Electrical Manufacturers' Club	50
Wire Inspection Bureau	24
Empire State Gas and Electric Association	75
American Association of Electric Motor Manufacturers	200
National Electric Light Association	3,065
Museum of Safety and Sanitation	50
Association of Edison Illuminating Companies	68
Technical Society of New York	150
Explorers Club	110
Society of Naval Architects and Marine Engineers	870
American Street and Interurban Railway Association	1,000
Illuminating Engineering Society	1,065
Municipal Engineers of City of New York	565

ATTENDANCE AT MEETINGS

Society	No.	Attendance
American Institute of Mining Engineers	4	349
The American Society of Mechanical Engineers	14	5,393
American Institute of Electrical Engineers	11	3,745
New York Electrical Society	3	761
New York Railroad Club	9	3,774
New York Telephone Society	9	2,314
American Society of Heating and Ventilating Engineers	3	364
Blue Room Engineering Society	12	415
Explorers Club	9	472
German Scientific Club	3	183
Western Electric Club	5	507
Technical Society of New York	10	261
American Street and Interurban Railway Association	2	49
Municipal Engineers of New York	9	1,404
Illuminating Engineering Society	7	501
Society of Naval Architects and Marine Engineers	2	301
American Society of Refrigerating Engineers	3	291
Railway Signal Association	2	324
Cast Iron Fittings Manufacturers Association	6	102
Association of Edison Illuminating Companies	4	60
Empire State Gas and Electric Association	5	134
New York Electrical Trade School	1	262
American Gas Institute	3	1,344
American Society for Promotion of Industrial Education	1	203
American Railway Master Mechanics	1	57

STUDENT BRANCHES, AM. SOC. M. E.

The following table gives the Student Branches of the Society with their officers:

STUDENT BRANCH	AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter		C. F. Hirshfeld
	1909			
Armour Inst. of Tech. Chicago, Ill.	March 9	C. F. Gebhardt	N. J. Boughton	M. C. Shedd
Leland Stanford, Jr., University, Palo Alto, Cal.	March 9	W. F. Durand	P. H. Van Etten	H. L. Hess
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. M. Russell	P. Gianella
State Agri. College of Oregon, Corvallis, Ore.	March 9	Thos. M. Gardner	J. J. Karstetter	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. A. Kirk	J. R. Jackson
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	H. S. Coleman	John Garver
New York Univ., New York.		C. E. Houghton		Andrew Hamilton
Univ. of Illinois, Urbana, Ill.		W. F. M. Goss	W. F. Colman	S. G. Wood
Penna. State College State College, Pa.				

THE SOCIETY'S HUDSON-FULTON EXHIBIT

Considerable interest was manifested in the Hudson-Fulton exhibit in the Council room of the Society. The total number of visitors who registered was 355, but 400 is a fair estimate of the total. The greatest registration for any one day was 52 on Monday, September 27.

A wide extent of territory was represented, including Connecticut, Delaware, Illinois, Maine, Massachusetts, Maryland, Michigan, Ohio, Pennsylvania, Rhode Island, Tennessee, Washington, D. C., Wisconsin, Canada, Japan and Switzerland.

In addition to the exhibits listed in the October Journal, Dr. Geo. F. Kunz has loaned a silver Hudson-Fulton medal and has presented to the Society the following:

Descriptive Guide to the Grounds, Buildings and Collections of the New York Botanical Garden.

List of Prints, Books, Manuscripts, etc., relating to Henry Hudson, the Hudson River, Robert Fulton and Steam Navigation, at the Lenox Branch of the New York Public Library.

The Indians of Manhattan Island and Vicinity, by Alanson Skinner, of the department of anthropology of the American Museum of Natural History.

The Wild Animals of Hudson's Day and the Zoölogical Park of our Day, by W. T. Hornaday, Sc.D., Director of the New York Zoölogical Park.

OTHER SOCIETIES

INTERNATIONAL SOCIETY FOR TESTING MATERIALS

Fully seven hundred delegates attended the fifth convention of the International Society for Testing Materials, held September 7–11, 1909, at Copenhagen, Denmark. The American members of that society in attendance were Dr. Charles B. Dudley, Mem.Am.-Soc.M.E., Altoona, Pa., official representative of the United States, Prof. Wm. K. Hatt, Lafayette, Ind., Richard L. Humphrey, Washington, D. C., Prof. Arthur N. Talbot, Urbana, Ill., Walter Wood, Mem.Am.Soc.M.E., Philadelphia, Pa., William R. Webster, Mem.-Am.Soc.M.E., Philadelphia, Pa., Tinius Olsen, Philadelphia, Pa., L. H. Fry, Mem.Am.Soc.M.E., Paris, technical representative in Europe of the Baldwin Locomotive Works, Prof. J. W. Richards, South Bethlehem, Pa., and Dr. Richard Moldenke, Mem.Am.Soc.M.E., Watchung, N. J. A very elaborate program was provided, beginning with an imposing ceremony in the great assembly hall of the University in the presence of all the members of the royal family.

Professor Heyn presented his report on the progress of metallography since the Brussels Congress, at the morning session of September 8, and in the afternoon William R. Webster, Mem.Am.-Soc.M.E., presented on behalf of International Committee No. 1 the specifications for iron and steel adopted respectively by America, England and Germany. The resolution was adopted in general and the committee instructed to continue the work of unification of iron and steel specifications. George Lloyd of England presented a resolution in behalf of the cast-iron side of Committee No. 1, in which attention was called to the growing specifications of foundry pig iron by analysis. Dr. Richard Moldenke, Mem.Am.Soc.M.E., was called upon by the chair to explain the situation more fully. In addition the committee instructed Walter Wood, Mem.Am.Soc.-M.E., to gather the necessary information relative to the unification of cast-iron pipe specifications. The reports on the nomenclature of steel and iron and on specifications for copper were also presented, but the former was not accepted.

On the following day the proposed specifications for wrought-iron

pipe received a full discussion resulting in the establishment of a commission to study the relation of the wear of a material to its hardness. Dr. Moldenke then delivered the report of Commission 25 on Methods of Testing Cast Iron, explaining the progress made and urging international action on the purchase of pig iron by chemical specifications. Electric and magnetic properties of metals for testing purposes were next taken up and discussed. The closing session included the reports on tests for endurance and quality in copper wire and impact tests.

It was voted that the next congress be held in the United States in 1912 and the invitation of the American Society for Testing Materials was accepted. Dr. Charles B. Dudley, Mem.Am.Soc.M.E., was formally elected president of the society amid great enthusiasm. The congress then adjourned, after listening to a lecture by J. E. Stead on The Use of the Microscope in the Shop and Mill for Iron and Steel. An extended trip was taken into Jutland after the congress.

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the regular fortnightly meeting of the American Society of Civil Engineers, October 6, papers were presented for discussion as follows: A Review of Chicago Paving Practice, by P. E. Green; The Purification of the Water Supply of Steelton, Pa., by James H. Fuertes.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

At a regular meeting of the Institute, held Friday evening, October 8, in the auditorium of the Engineering Societies Building, 29 West 39th Street, New York, a paper was presented by John B. Taylor, of the General Electric Company, Schenectady, N. Y., on Telegraph and Telephone Systems as Affected by Alternating-Current Lines. At the November meeting, on the twelfth of that month, Dr. Cary T. Hutchinson, Mem.Am.Soc.M.E., will present a paper on The Electric System of the Great Northern Railway Company at Cascade Tunnel.

TECHNICAL SOCIETY OF BROOKLYN

In the first October meeting of the Technical Society of Brooklyn, President M. C. Budell presented his annual report. The election of officers for the coming year resulted as follows: M. C. Budell, President; Val. Wolz, Vice-President; H. Dann and A. Wittel, Sec-

retaries; Dr. W. Schad, Treasurer; E. Obermuller, Librarian; Bartholomew Viola, Mem.Am.Soc.M.E., Otto Sturm and J. Geo. Ament, chairmen of standing committees.

AËROPLANE FLIGHTS DURING THE HUDSON-FULTON CELEBRATION

A notable achievement in navigation of the air marked the closing days of the recent Hudson-Fulton celebration in New York. The aëronautic committee of the Hudson-Fulton Commission had contracted with Wilbur Wright and Glenn H. Curtiss for a series of aëroplane flights up the Hudson River.

Curtiss was unable to make any save short flights over the starting place, the parade ground of the army station at Governor's Island. On September 29, however, Wright encircled the Statue of Liberty in New York harbor and later made two circuits of the parade ground. On October 4, Wright sailed up the Hudson to Grant's tomb, encircled the foreign warships anchored at that point and returned over the river to Governor's Island. A flight over the city, planned for the afternoon of the same day, was not made owing to an accident to the engine. Further flights were not possible owing to Wright's Washington engagements. Curtiss essayed a flight early in the morning of September 29, but remained in the air less than a minute owing to a minor defect in the machine. Some difficulty was experienced in starting, as the wheels on which the machine was mounted sank into the sandy filling of the parade ground.

Wright's machine was fitted with a canoe, as shown in the illustration, in case of accident while over the water. The engine is started by turning the two 8-ft. propellers at the rear of the machine.

The flight around the Statue of Libe ty started at 10.18 a.m. After leaving the monorail the machine made a gradual ascent, and at a height of forty feet made the circuit of the parade ground. Then re-circling it, the machine turned toward a point to the north of the statue. Passing within 20 ft. of the statue, which is 305 ft. high, the machine was seen to be at about the same height as the breast of the statue. After describing a figure 8 and flying over ships at anchor in the harbor, Wright turned his machine toward the Jersey shore for a short distance and then wheeled back to the starting point, having been in the air about seven minutes, covering a distance of six miles

In the afternoon the machine encircled the parade ground twice, traveling against the wind at a speed of about forty miles and with the wind at about fifty-seven miles. At no time did the wind exceed ten miles an hour.

The flight up the Hudson started at 9.56 a.m. on October 4, the wind blowing at about twelve miles an hour. The machine rose rapidly from the monorail and passed over the sea wall at about forty or fifty feet heading toward the mouth of the Hudson. To avoid trouble with air currents caused by the high buildings on

WILBUR WRIGHT STANDING BESIDE HIS AËROPLANE. THE CANOE IS CARRIED IN CASE OF ACCIDENT WHILE OVER THE WATER

the New York side of the river, Wright flew close to the Jersey shore, saluted by shrieking whistles and cheering spectators. At one point the height was about three hundred feet. At 130th Street Wright turned the machine in a wide circle to retrace his path.

During the return flight the machine was brought down to within about fifty feet of the water, afterward soaring to a higher level. When near the island a gradual descent was made, the machine landing about twenty yards from the starting point.

The aëroplane had left the monorail at 9.56 o'clock and landed at 10.29 to 10.33 o'clock, so that the time in the air was 33 min.

The Wright Aëroplane Flying over the Hudson River on the Return Trip from Grant's Tomb to Governor's Island

33 sec. The distance in a straight line is 18.3 miles, but the actual distance traveled was nearer twenty-four miles. The average speed was approximately $45\frac{1}{2}$ miles an hour and the average altitude 200 ft.

NECROLOGY

THOMAS HALLETT BRIGGS

Thomas Hallett Briggs was born on August 21, 1870 in New York. He received his education in the public schools of Brooklyn, N. Y., and finished with a technical course at Cooper Union. During his studies at Cooper Union, he was employed in the drafting room of the Logan Iron Works of Brooklyn, with which company he remained for fourteen years. His work there covered not only drafting-room work, but shop inspection, and he finally became outside representative. He became associated wth the M. H. Treadwell Co., New York, as salesman, in 1904, which position he held until the time of his death on September 24, 1909. Mr. Briggs was a member of the Society of Gas Engineers, and entered this Society as an Associate in 1900.

PERSONALS OF THE MEMBERSHIP AM. SOC. M. E.

Kilburn E. Adams has severed his connection with the Wm. Underwood Co., and has accepted the position of mechanical engineer with the Boston & Albany Railroad, Boston, Mass.

Charles M. Allen, professor of experimental mechanical engineering in Worcester Polytechnic Institute, has been appointed professor of hydraulic engineering in the same institution.

A. Bement has been appointed a member of a committee named by the Western Society of Engineers, to coöperate with the Chicago Harbor Commission.

At the regular meeting of the Engineers' Club of St. Louis, Wednesday evening, October 12, William H. Bryan, Mem.Am.Soc.M.E., presented a paper on Going Value as an Element in the Appraisal of Public Utilities.

Philip L. Clarke has resigned his position in the experimental turbine department of the General Electric Co., Schenectady, N. Y., and is now in the employ of White & Newcomb of Mexico City.

Claude E. Cox has resigned his position as engineer and assistant manager of the Interstate Automobile Co., Anderson, Ind., and has assumed a similar position with the Wilcox Motor Car Co., Minneapolis, Minn.

Arthur M. Dean, formerly in the employ of the Mora Motor Car Co., Newark, N. Y., has accepted a position with the Matheson Motor Car Co., Wilkes-Barre, Pa.

Harrington Emerson is the author of a book on Efficiency as a Basis for Operation and Wages.

William D. Ennis has contributed an article on Materials for Pipe Lines to the September 21 issue of *Power and the Engineer*.

Carl E. Hardy, recently located at Cartersville, Ga., has been made assistant superintendent of shops, manufacturing department, U. S. Navy Yard, Mare Island, Cal.

Edward J. Kunze, formerly consulting engineer, Newark, N. J., has been appointed instructor in steam and gas engineering, University of Wisconsin, Madison, Wis.

H. B. MacFarland, formerly consulting engineer, Chicago, Ill., has been appointed engineer of tests, Atchison, Topeka & Sante Fe Railway Co., Topeka, Kansas.

F. W. Mahl has become associated with the Union Pacific System and Southern Pacific Co., Chicago, Ill. He was formerly in the employ of the Colorado and Southern Railway Co., Denver Colo., as mechanical engineer and general purchasing agent.

M. C. Maxwell, of the department of applied mechanics, Pratt Institute, delivered the opening address before the Modern Science Club of Brooklyn, N. Y., October 5.

Harry de B. Parsons delivered the address on the occasion of the Hudson-Fulton celebration of the Clarkson School of Technology, on the evening of September 29, entitled, A Sketch of the Commercial Development during the Last Three Hundred Years, 1609–1909.

Arthur W. Richter, professor of experimental engineering, University of Wisconsin, has been appointed dean of the college of engineering of the University of Montana, Helena, Mont.

H. W. Rowley, until recently sales engineer of the New York office of the Allis-Chalmers Co., has opened an office as special representative for that company in the Evans Building, Washington, D. C.

William E. Smith has accepted a position with the Babcock & Wilcox Co., Barberton, O. He was until recently connected with the Delaware, Lackawanna & Western Railroad Co., Scranton, Pa.

E. R. Stoughton has entered the service of Baird & West, Detroit, Mich. He was recently associated with the U. S. Heater Co., Detroit, Mich.

Robert I. Todd, vice-president of the Terre Haute, Indianapolis & Eastern Traction Co., has been made general manager. Mr. Todd is also vice-president and general manager of the Indianapolis Traction and Terminal Co.

A. F. Van Deinse, who recently completed the installation of a power plant for the El Tiro Copper Co., Silverbell, Ariz., has accepted a position with the Westinghouse Electric and Manufacturing Co., and will be located at their El Paso, Texas, office.

H. H. Vaughan presented a paper on Locomotive Counter-balancing at the September 7 meeting of the Canadian Railway Club.

HISTORY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Preliminary Report of the Committee on Society History

Chapter X—*Continued*

CONTINUED GROWTH OF THE SOCIETY

The summer meeting of 1895 was held at Detroit, in June, and, as usual with the gatherings in the summer, the business transacted was kept at a minimum, being limited mainly to the necessary action upon candidates for membership, and similar routine business.

260 Mention has been made of the manner in which the general industrial situation is reflected in the meetings of the Society, and this fact was emphasized by the number and variety of papers presented at the Detroit meeting, and the bearing which they have had upon subsequent developments. Among the most important papers, viewed in this light, was undoubtedly that of F. W. Taylor, entitled A Piece-Rate System, introducing for discussion the differential piece-rate system afterwards more fully developed by the author, as well as the important idea of analyzing shop operations into their elementary details and determining the time required for these, so that their combinations cover the questions arising for the fixing of rates on various kinds of work. The methods employed for determining the laws governing the operations of metal-cutting, as laid down in this paper, have since been far more fully developed, and their investigation had doubtless much to do with the introduction of modern rapid-cutting tool steels. The discussion which this paper by Mr. Taylor elicited, showed very clearly the interest which the members of the

Under the direction of the Council the Committee on Society History has arranged to present the results of its investigations to the members of the Society. The Preliminary Report will appear in The Journal of the Society from month to month, and thus enable the matter to be open to comment during its completion. It is especially desired that any member who may be in the possession of facts or information bearing upon the various points as they are thus made public will communicate with the committee, in order that the final and completed report may have the advantage of the collaboration of the membership at large.

Society took in matters relating to works management, an interest which has since become most widely extended and practically applied.

261 Another important contribution to engineering practice, presented at the Detroit meeting, resulted from the report of the committee on standard tests and methods of testing materials, presented by G. C. Henning, and supplemented by a report upon the transverse strength of cast iron by W. J. Keep, whose previous paper upon the strength of cast iron has already been mentioned. The exhaustive tests made by Mr. Keep upon the properties of cast iron, and the practical nature of his work and the conclusions drawn by him, render his contributions to the subject most valuable and reliable. This paper was followed by another, presenting to the Society and to the engineering profession Mr. Keep's study of "cooling curves," these curves showing the nature and extent of the shrinkage of the metal while cooling, and enabling information as to the strength and constitution of the casting to be derived.

262 The social features of the Detroit meeting were of an especially agreeable nature, including an excursion on the lake steamer City of Cleveland, a reception at the Detroit Club, and numerous visits to important industrial establishments.

263 Just prior to the Detroit meeting the Society experienced another loss from the ranks of its past-presidents, when Eckley B. Coxe, who had filled the presidential office for the two terms of 1893 and 1894, passed away on May 13, 1895. This loss was soon followed by another, most unexpected and sad, the death of the president of the Society, E. F. C. Davis, who was killed by a fall from his horse on August 6, 1895.

264 At the opening of the annual meeting in New York the first business was the announcement by Mr. J. F. Holloway of the action of the Council in the appointment, under the rules, of the senior vice-president, Charles E. Billings of Hartford, Conn., as president to fill the unexpired term of Mr. Davis. The address of Mr. Billings, discussing modern improvements in the drop press, formed another of the admirable monographs resulting from the adoption of the plan of selecting subjects intimately connected with the professional and practical work of the speaker. The tellers of election at this meeting announced the election of John Fritz to the office of president for the ensuing year. At this meeting there was presented a progress report of a committee on fireproof tests, a work undertaken in connection with similar committees representing the Fire Underwriters of New York and the Architectural League of New York.

265 At an example of the position which the Society had acquired as an organization recognized as a conservator of relics and documents relating to the historical side of engineering work, mention may be made of the fact that it was selected to receive the original autograph drawing of the steamboat Fulton, the first steamboat built for service on Long Island Sound. The drawing bears the date of March 1, 1813, as well as Fulton's signature. This drawing, formerly belonging to the late George L. Schuyler, of New York City, was presented to the Society by his daughter, Miss Louisa Lee Schuyler. The Society had already received, as a gift from Dr. Thomas Egleston, the handsome mahogany dining table formerly belonging to Fulton, so that it was already well on the way to become the recognized custodian of such relics.

266 At the same meeting the attention of the members was called to an excellent oil portrait of Captain John Ericsson, the work of the Swedish artist Ballin, a picture which had formerly belonged to Captain Ericsson, but after his death found its way into the hands of a dealer, from whom it was purchased by the Secretary of the Society.

267 The papers of the New York meeting of 1895 included a number devoted to the subject of power-plant design, including both steam and water power. Among the latter, attention may be called to the exhaustive paper upon water power by the veteran hydraulic engineer, Samuel Webber, this being a very full historical review of the development of the hydraulic turbine in America, especially in connection with the use of the power of the Merrimac river, and other power sources in New England. A paper by Samuel McElroy, upon the development of the water power of Caratunk Falls, in Maine, furnished an admirable pendant to the contribution of Mr. Webber, especially as showing the manner in which a hydraulic-power site may be investigated prior to the design of the plant, taking into account the experience gained in previous installation.s

268 Other papers at this meeting related to the use of the throttling calorimeter, for the purpose of determining the amount of moisture in steam; an important study, by Dr. Charles E. Emery, upon tests of steam boilers with different kinds of coal; and a discussion, by Prof. John H. Barr, of the proportions of high-speed engines. It is interesting to note that at this meeting the steam turbine began to receive serious discussion, a report of a test upon a small machine of the De-Laval type, by Professor Goss, attracting attention.

269 In accordance with arrangements made at the time of the Detroit meeting, the summer convention of 1896 was held at St. Louis,

Mo., in May. This meeting was devoted very largely to the discussion of matters relating to steam power plants. Dr. R. H. Thurston contributed a very complete paper upon superheated steam, while methods of determining the presence of moisture in coal received attention; and there was discussion of the performance of mechanical stokers. A paper by L. R. Alberger, upon what has since been called a "cooling tower" for enabling the use of the same condensing-water repeatedly, may be referred to as early mention of what has since become a standard piece of apparatus, this being but one example of the manner in which the meetings of the Society have served to bring into notice devices which have subsequently taken important places in commercial engineering work.

STRESSES IN REINFORCED-CONCRETE BEAMS

COMPARISON OF EXPERIMENTAL RESULTS WITH RESULTS OBTAINED FROM THE USE OF THREE THEORIES OF DISTRIBUTION OF STRESSES

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Non-Member.

Many experiments have been performed on the breaking strength of reinforced-concrete beams, and in the course of them many observations have been made to determine quantitatively some of the phenomena attendant upon the application of the breaking load, and also upon that of smaller loads. Nevertheless it is well known that the observations made thus far are not sufficient to furnish the means for determining the actual distribution of the stresses, and hence for the deduction of reliable formulae for the computation of the direct stresses, shearing stresses, diagonal stresses, deflections, position of the neutral axis, etc., under a given load.

2 The test of the validity of such formulae should be their agreement with the results of experiments when the loads employed are about one-fourth or one-third the ultimate loads, because, when the loads are greater, the ratio of stress to strain varies very considerably for the different fibres, while for loads smaller than one-fourth of the ultimate, unknown initial stresses are liable to exert so great an influence as to interfere with the deductions.

3 The object of this paper is to make a comparison of (*a*) the position of the neutral axis, (*b*) the stress in the steel, (*c*) the stresses in the concrete, and (*d*) the deflection, as determined by experiment, with the same quantities as computed by three well-known theories of the distribution of the stresses. The comparison was made in the cases of eleven beams, in the testing of which the necessary observations

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were taken. Of the eleven, five were tested in the laboratory of Applied Mechanics of the Massachusetts Institute of Technology, and six in the laboratory of the University of Illinois.

4 The reinforcement consisted in each case of one or more longitudinal bars placed near the bottom of the beam, and equal loads were applied at the two points which divided the span into thirds.

5 The three theories employed in making the calculations, all of which assume that at any given section the strain in any fibre is proportional to the distance of the fibre from the neutral axis, will be denoted by *A*, *B* and *C* respectively, and may be described as follows, the notation used in lettering the figures being explained subsequently:

> *A* This theory, which is very extensively employed, makes the assumption that at any given section none of the

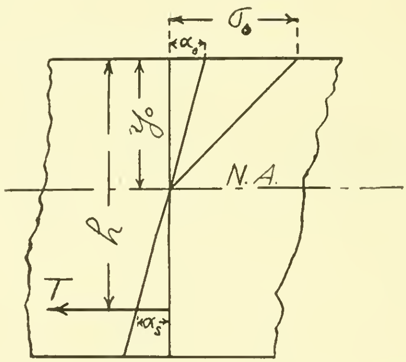

FIG. 1 THEORY A: DISTRIBUTION OF STRAINS AND STRESSES AT A CROSS-SECTION

> concrete below the neutral axis can be relied upon to resist tension; and further that the stress is proportional to the strain not only in the steel but also in the concrete.

6 This method is used, by those who employ it to determine (*a*) the position of the neutral axis, (*b*) the stress in the steel, (*c*) the stress in the concrete, and sometimes the shearing stress at the neutral axis; but practically no attempt is made to compute the deflections by it. Nevertheless for the purpose of comparison, deflection formulæ deduced on this basis will be given. The distribution of the strains and stresses at a cross section is shown in Fig. 1.

B This theory, which was proposed by Prof. A. N. Talbot, also makes the assumption that at any given section none of the concrete below the neutral axis can be relied upon to resist tension; but instead of assuming the proportionality of stress to strain in the concrete, the assumption is made that the stress at any fibre can be represented graphically by the corresponding abscissa of a parabola drawn through the neutral axis; the axis of the parabola being at right angles to the section, and its vertex at the end of the abscissa which would represent the crushing strength per square inch of the concrete, were the plot continued to such a height as to correspond to this crushing strength.

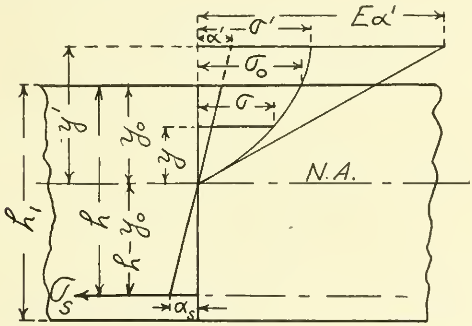

Fig. 2 Theory B: Distribution of Strains and Stresses at a Cross-section

7 The quantities calculated by this theory are the same as in case *A*, and again deflection formulae will be deduced on this basis for the same reason as there stated. The distribution of the strains and stresses at a cross section is shown in Fig. 2.

C The third theory is that proposed by Mr. Considère. He claims that whereas in a plain concrete beam, the concrete on the tension side cracks when the extension has reached 0.01 to 0.02 per cent, in a reinforced-concrete beam the concrete on the tension side can undergo many times this extension without cracking.

8 Among the tests which he cites in confirmation of this view is the following: He says that he subjected one reinforced-concrete beam to a load that produced in the lower fibre of the concrete an

elongation of 0.063 per cent as determined by measurement, and another such beam to a load that produced in the lower fibre of the concrete an elongation of 0.13 per cent, that he then removed the loads, chipped off the concrete below the reinforcement, and removed the reinforcing bars, after which he smoothed off the lower surface of the remaining portion of the beam and sawed out a concrete plank from the lower side. He says that not only did this plank not fall to pieces, but that on loading it transversely it bore as much as would be expected from a plain concrete plank of the same dimensions.

9 In view of the above, Mr. Considère suggests that the distribution of the stress at a section is as shown in Fig. 3, the compressive strength being represented by the triangle *OABO*, and the tensile strength in the concrete by the trapezoid *OCEFO*, the value of *CD*

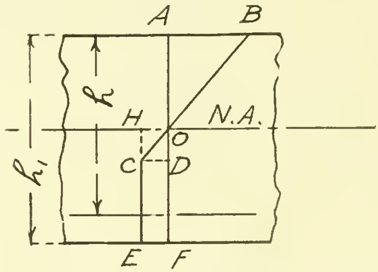

Fig. 3 Distribution of Strains and Stresses According to Considère's Theory

being equal to the yield point of the concrete in tension; and that for greater elongations the tensile strength does not increase.

10 However, inasmuch as the assumption of this distribution would lead to great complexity in the calculations, he proposes as a sufficiently close approximation that for the trapezoid *OCEFO* in Fig. 3 we substitute the rectangle *OHEFO*. In this paper this approximation will be made in obtaining the formulae on the basis of *C*.

11 Before obtaining the formulae needed for making the calculations, the notation used throughout will be explained.

Let α_0 = strain in concrete at upper fibre of beam.

α_s = strain in steel reinforcement.

E = ratio of stress to strain in concrete. In *B* this will denote the initial ratio of stress to strain.

E_s = ratio of stress to strain in steel.

$r = \frac{E_s}{E}$

σ_o = compressive outside fibre stress per square inch in concrete.

σ_s = stress per square inch in steel.

a_s = area of section of steel reinforcement in square inches.

$T = \sigma_s a_s$.

b = breadth of beam.

$n = \frac{r a_s}{b}$

h = distance from top of beam to centre of reinforcement, inches.

h_1 = total depth of beam, inches.

y_o = distance from top of beam to neutral axis.

ρ = radius of curvature of vertical longitudinal section of neutral layer.

W = total load applied.

l = span, inches.

v = deflection at distance x from left-hand support.

v_o = greatest deflection, i. e., deflection at middle.

The above is the notation needed for A .

12 In B the same notation is used with the following in addition:

Let y = distance of any fibre above the neutral axis.

y^1 = distance above neutral axis at which the fibre would be subjected to the crushing strength.

α = strain of fibre at distance y above neutral axis.

α^1 = ultimate compressive strain of concrete.

σ = stress in fibre at distance y above neutral axis.

σ^1 = ultimate compressive strength of concrete.

$q = \frac{\alpha_o}{\alpha^1}$

$n_1 = \frac{3\, r\, a_s}{b\,(3 - q)}$

d_1 = distance above neutral axis to point of application of resultant of compression.

d_2 = distance below top of beam to point of application of resultant of compression.

13 In C the same notation is used with the following in addition:

Let t = yield point of concrete in tension.

$d = h_1 - h$.

FORMULAE

14 Taking up the three theories successively, the formulae needed to make the computation of the values of y_0, σ_s, σ_0 and v_0 will now be given, the deduction being left to the reader. By Method A:

A

$$y_o = \sqrt{n^2 + 2\,n\,h} - n \quad \text{(1)}$$

$$\sigma_s = \frac{3\,M}{(3\,h - y_o)\,a_s} \quad \text{(2)}$$

$$\sigma_o = \frac{6\,M}{(3\,h - y_o)\,by_o} \quad \text{(3)}$$

$$v_o = -\frac{23\,Wl^3}{1296\,A} \quad \text{(4)}$$

where

$$A = E\left\{ra_s\,(h - y_o)^2 + \frac{b\,y_o^3}{3}\right\}$$

B

15 In order to find y_0, σ_s, and σ_0 by Method B, we have the following equations, all of which include q:

$$y_o = \sqrt{n_1^2 + 2\,n_1\,h} - n_1 \quad \text{(5)}$$

$$\sigma_s = \frac{M}{a_s\left\{h - y_o\,\frac{4-q}{4\,(3 - q)}\right\}} \quad \text{(6)}$$

$$\sigma_o = \frac{M}{b\,y_o\left\{\frac{3-q}{3\,(2 - q)}\,h - \frac{4-q}{12\,(2-q)}\,y_o\right\}} \quad \text{(7)}$$

Hence before we can find the values of y_0, σ_s and σ_0 we need to determine q, and this will have to be done approximately. For this purpose we can use the equation:

$$q^2 - 2q = -\frac{\sigma_o}{\sigma^1} \quad \text{(8)}$$

16 Plot a curve having $\frac{\sigma_0}{\sigma^1}$'s for abscissae, and q's for ordinates, then using for σ_0 a first approximation to its value, determine a first

approximation for q. Then determine a second approximation for δ_0 and from it a second approximation for q, etc.

17 In the calculations made here, with the load approximately one-third of the breaking load, the value that has been employed is $q = 0.2$.

18 For the deflection we have

$$v_o = -\frac{23\,Wl^3}{1296\,A} \quad \text{(9)}$$

where

$$A = E\left\{r\,a_s\,(h - y_o)^2 + b\,y_o^3\,\frac{8 - 3q}{24}\right\}$$

C

19 In order to obtain y_0 by Method C we need to solve the equation of the fourth degree in y_0:

$$b\,y_o^4 + 2\left\{b\,(h + d) + 3\,r\,a_s\right\}y_o^3 - 3\left\{b\,(h + d)^2 + 6\,r\,a_s h - 2\frac{M}{t}\right\}y_o^2 + 6\,r\,a_s\left\{\frac{2\,M}{t\,b} + 3\,h^2 - d^2\right\}y_o - 6\,r\,a_s\,h\left\{\frac{2\,M}{t\,b} + h^2 - d^2\right\} = 0 \quad \text{(10)}$$

20 The solution can be readily effected graphically for any numerical case by writing u equal to the entire left-hand side of the equation, and plotting the resulting curve with y_0's as abscissae and u's as ordinates; then the value of y_0 where this curve crosses the axis of abscissae will be the value of y_0 desired. Of course the equation has four roots, but the one required can be easily identified as it must give a neutral axis that lies within the section.

21 In solving this equation, some value of t, the tensile yield point of the concrete, must be used. Considère suggests 170 lb. per sq. in. for the concrete used by him, which was about six months old and of a composition of nearly 1 – 2.5 – 2.5.

22 In the calculations made in this paper, t = 100 lb. per sq. in. has been used, as the concrete was from 30 to 60 days old and its composition was 1 – 3 – 6. After y_0 has been found we can find σ_s and σ_0 from the following equations respectively:

$$\sigma_s\,a_s\,\frac{3\,h - y_o}{3} = M - t\,b\,(h_1 - y)\,\frac{3\,h_1 + y_o}{6} \quad \text{(11)}$$

$$\sigma_o\,\frac{b\,y_o}{2}\,\frac{3\,h - y}{3} = M + t\,b\,(h_1 - y_o)\,\frac{2\,h - h_1 - y_o}{2} \quad \text{(12)}$$

or more easily from the formulae.

$$\sigma_o = \frac{t\,b\,(h_1 - y_o)}{\dfrac{b\,y_o}{2} - r\,a_s\,\dfrac{h - y_o}{y_o}} \quad \text{..................(13)}$$

$$\sigma_s = r\,\sigma_o\,\frac{h - y_o}{y_o} \quad \text{....................(14)}$$

For the deflection we have

$$v_o = -\frac{23\,W\,l^3}{1296\ A} \quad \text{..................(15)}$$

where

$$A = E\left\{\frac{r\,a_s\,(h - y_o)\ (2\,h - h_1 - y_o)}{2} + \frac{b\,y_o{}^2\ (3\,h_1 + y_o)}{12}\right\}$$

COMPARISON OF THE VALUES OF y_0, σ_s σ_0 AND v_0 AS COMPUTED BY THE VARIOUS THEORIES WITH THOSE DETERMINED BY EXPERIMENT

23 This comparison is exhibited in the tables. The first five beams were tested in the laboratory of applied mechanics of the Massachusetts Institute of Technology, and for these we have used E_s = 28,000,000 and E = 2,335,000, and hence r = 12. The last six beams were tested in the laboratory of the University of Illinois, and for these we have used E_s = 30,000,000, and E = 2,000,000, and hence r = 15. All eleven were made of 1 – 3 – 6 concrete, the ages being given in the tables. All were loaded with two equal loads applied at points dividing the span into thirds.

TABLE I DETAILS OF REINFORCED CONCRETE BEAMS

All Beams Loaded at Third Points

Designation of Beam	Age Days	b Inches	h Inches	h_1 Inches	Span Feet	Rods: Number	Rods: Size Inches Round	Steel a_S Area in Square Inches	p*
Massachusetts Institute of Technology									
A—1	53	8	10	12	11	1	1†	1.00	1.25
A—2	49	8	10	12	11	1	1‡	1.00	1.25
B—3	43	8	10	12	11	2	$\frac{3}{4}$†	1.125	1.41
C—5	35	8	10	12	11	4	$\frac{1}{2}$†	1.00	1.25
E—9	54	8	10	12	11	2	$\frac{7}{8}$‡	1.53	1.91
University of Illinois									
11	65	8	10	11	12	4	$\frac{1}{2}$	0.785	0.99
27–'04	63	12	12	13½	14	4	$\frac{3}{4}$†	2.25	1.56
28	60	8	10	11	12	4	$\frac{3}{4}$	1.77	2.22
33	60	8	10	11	12	3	$\frac{3}{4}$	1.325	1.66
35	60	8	10	11	12	3 2	$\frac{1}{2}$ $\frac{3}{4}$	1.473	1.84
45	61	8	10	11	12	3 2	$\frac{1}{2}$ $\frac{3}{4}$	1.473	1.84

* Reinforcement of area above center line of steel, per cent.

† Square.

‡ Twisted.

TABLE 2 DATA FROM TESTS ON REINFORCED CONCRETE BEAMS

All Beams Loaded at Third Point

Designation of Beam	Breaking Load*	Nearest $\frac{1}{3}$ Load†	Inches Actual (Plot): y_0	Inches Actual (Plot): σ_0	Inches Actual (Plot): σ_S	Deflection: Load Considered W	Deflection: v_0 (Plot)
Massachusetts Institute of Technology							
A—1	15250	5250	5.4	726	7941	4000	0.0731
A—2	16500	5250	5.3	650	7644	4000	0.0749
B—3	15950	5250	5.5	565	6615	4000	0.0660
C—5	16240	4600	4.6	781	8246	4000	0.1015
E—9	22250	6250	5.1	776	7563	5000	0.0769
University of Illinois							
11	11000	4000	4.8	740	11700	4000	0.175
27–'04	26900	9000	6.8	680	8250	9000	0.162
28	14300	5000	5.8	760	7800	5000	0.141
33	14400	5000	4.9	580	9000	5000	0.137
35	15000	5000	6.0	660	6750	5000	0.100
45	12400	4000	6.0	660	6750	4000	0.150

* Exclusive of weight of beam.

† Used in plots and in calculation for y_0, σ_S, σ_0.

TABLE 3 RESULTS OBTAINED BY EXPERIMENT AND BY COMPUTATION

Massachusetts Institute of Technology Beams: r = 12, E = 2,335,000.
University of Illinois Beams: r = 15, E = 2,000,000.

Designation of Beam	y_o Actual or Plot	y_o A	y_o B q = 0.20	y_o C t = 100	σ_o Actual or Plot	σ_o A	σ_o B q = 0.20	σ_o C t = 100
			Massachusetts Institute of Technology					
A—1	5.4	4.18	4.29	4.94	726	801	760	759
A—2	5.3	4.18	4.29	4.94	650	801	760	759
B—3	5.5	4.36	4.47	5.10	565	774	734	640
C—5	4.6	4.18	4.29	5.06	781	703	666	653
E—9	5.1	4.86	4.97	5.45	776	844	802	810
			University of Illinois					
11	4.8	4.15	4.27	4.93	740	670	634	645
27–'04	6.8	5.88	6.01	6.60	680	711	678	690
28	5.8	5.49	5.59	5.98	760	669	638	662
33	4.9	5.00	5.10	5.54	580	722	686	717
35	6.0	5.17	5.28	5.71	660	701	667	675
45	6.0	5.17	5.28	5.83	660	561	534	548

TABLE 4 RESULTS OBTAINED BY EXPERIMENT AND BY COMPUTATION

Massachusetts Institute of Technology Beams: r = 12, E = 2,335,000.
University of Illinois Beams: r = 15, E = 2,000,000.

Designation of Beam	σ_s Actual or Plot	σ_s A	σ_s B q = 0.20	σ_s C t = 100	v_o Actual or Plot	v_o A	v_o B q = 0.20	v_o C t = 100
			Massachusetts Institute of Technology					
A—1	7941	13420	13510	9333	0.0731	0.1163	0.1193	0.0921
A—2	7644	13420	13510	9333	0.0749	0.1163	0.1193	0.0921
B—3	6615	12000	12100	7374	0.0660	0.1076	0.1105	0.0865
C—5	8246	11755	11840	7650	0.1015	0.1163	0.1193	0.0887
E—9	7563	10720	10810	8110	0.0769	0.1105	0.1139	0.0942
			University of Illinois					
11	11700	14190	14210	9950	0.175	0.1778	0.1824	0.1500
27–04	8250	11160	11240	8468	0.162	0.1822	0.1878	0.1573
28	7800	8296	8386	6672	0.141	0.1346	0.1400	0.1216
33	9000	10880	10960	8662	0.137	0.1592	0.1647	0.1406
35	6750	9842	9926	7609	0.100	0.1501	0.1549	0.1329
45	6750	7890	7941	5878	0.150	0.1201	0.1240	0.1033

TABLE 5 COMPARISON OF RESULTS

Per cent of Variation of Results on Tables 3 and 4 from the Actual Values Determined by Experiment

Designation of Beam	y_0 A	y_0 B	y_0 C $t = 100$	σ_s A	σ_s B	σ_s C $t = 100$
Massachusetts Institute of Technology						
A—1	−22.59	−20.56	−8.52	69.00	70.13	17.54
A—2	−21.12	−19.05	−6.67	75.60	76.74	22.09
B—3	−20.73	−18.73	−7.27	81.41	82.92	11.47
C−5	− 9.13	− 6.74	10.00	42.55	43.53	−7.23
E−9	− 4.71	− 2.55	6.86	41.74	42.93	7.24
University of Illinois						
11	−13.54	−11.04	2.71	21.28	21.45	−14.96
27	−13.53	−11.61	−2.94	35.27	36.24	2.64
28	− 5.35	− 3.62	3.11	6.36	7.51	−14.45
33	2.04	4.09	13.06	20.83	21.78	− 3.76
35	−13.89	−12.00	−4.84	45.81	47.05	12.72
45	−13.84	−12.00	−2.84	16.89	17.65	−12.91
Average...	−12.40	−10.32	0.24	41.52	42.55	1.85

Values less than the actual are called negative.

TABLE 6

Per Cent of Variation of Results on Tables 3 and 4, from the Actual Values Determined by Experiment

Designation of Beam	σ_0 A	σ_0 B	σ_0 C $t = 100$	v_0 A	v_0 B	v_0 C $t - 100$
Massachusetts Institute of Technology						
A—1	10.33	4.68	4.55	59.09	63.20	25.99
A—2	23.23	16.92	16.77	55.27	59.23	22.96
B—3	36.99	29.91	13.27	63.03	67.44	31.07
C—5	− 9.98	−14.72	−16.39	14.58	17.54	−12.61
E—9	8.76	3.35	4.38	43.70	48.11	22.50
University of Illinois						
11	− 9.46	−14.34	−12.83	1.60	4.23	−14.29
27	4.56	− 0.29	1.47	12.47	15.92	− 2.90
28	−11.98	−16.05	−12.89	− 4.54	− 0.71	−13.76
33	18.28	18.28	23.62	16.20	20.22	2.63
35	6.21	1.06	2.27	50.01	54.90	32.90
45	−15.00	−19.10	−16.97	−19.93	−17.34	−31.15
Average...	6.19	0.88	0.66	26.50	30.25	5.76

Values less than the actual are called negative.

REMARKS AND CONCLUSIONS

24 The results seem to warrant the statement in Par. 1 that "the observations made thus far are not sufficient to furnish the means for determining the actual distribution of the stresses, and hence for the deduction of reliable formulae for the computation of the direct stresses, shearing stresses, diagonal stresses, deflections, position of the neutral axis, etc., under a given load." It follows therefore that whichever of the theories is adopted for practical use, it can be regarded only as a sort of working hypothesis.

25 It seemed therefore desirable to compare the results of these three well-known theories with those obtained by experiment. This comparison can best be made by a detailed study of the tables, especially Table 5 and Table 6.

26 However, it seems plain, as far as the evidence of these eleven tests goes, that in deducing the values of y_0 and σ_s theory C gives results much nearer those determined by experiment than either A or B, and the same is true to a lesser degree in the case of v_0, whereas the differences are not so marked in the case of σ_0.

27 It also seems hopeless to obtain a reliable deflection formula without taking into account the tension in the concrete.

28 Of course the computations are more easily made when A is used rather than B or C, but in the cases of B and C the complexity is not so great when designing a beam as when determining the stresses in a given beam under a given load.

PUMP VALVES AND VALVE AREAS

By A. F. Nagle, South Bethlehem, Pa.

Member of the Society

There has grown up a custom of specifying in water works pumping engine specifications that the area through the valves shall exceed the area of the plunger by a certain percentage thereof, varying from 25 to 125 per cent of increase. It is my purpose to demonstrate that the probable intent of the writer of this clause in the specification is not obtained in practice, namely, a low velocity through the valve and consequent low loss of head.

2 The above form of expression, namely, proportioning the valve area to the plunger area, is defective because (*a*) it fails to distinguish between the valve-seat area and the circumferential area of the valve at an assumed or specified lift; (*b*) it leads to an absurdity unless coupled with the length of stroke and the number thereof.

3 To the first criticism it may be replied that the engine builder interprets the clause to mean the net area through the valve seats, but the city's engineer occasionally requires the circumferential area. To this the builder will not seriously object, for he simply increases the *possible* lift, knowing very well that "it will never go there."

4 The second criticism can be best illustrated by the following example: Compare two pumps, each making 25 r.p.m. one having a plunger $6\frac{1}{2}$ in. in diameter by 60 in. stroke, and the other a plunger of 13 in. diameter by 15 in. stroke. Precisely the same volume of water passes through the two pumps, yet the rule laid down in the specification would require for one pump four times the valve area of the other.

5 What is the real purpose in specifying anything at all about valve area? Evidently the same that is sought in limiting the plunger travel per minute, and founded upon the law that in a pumping engine, low velocities of water are conducive to low cost of operation, but proportionately great cost of construction, and conversely,

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high velocities imply high cost of operation but lower cost of construction; hence, very properly, the buyer should specify the maximum velocity he will accept.

6 Briefly, it may be said that city water works engines are now quite generally limited to about 250 ft. of plunger travel per min., although frequent attempts are made with special designs to increase this travel to nearly twice this amount. This plunger travel with 5 to 1 connecting rod, entails a maximum plunger velocity of 6.67 ft. per sec., and the *head due to this velocity* is 0.30 lb. per sq. in. It is desirable to speak of the maximum plunger velocity rather than the mean, because that governs the maximum valve area to be provided.

7 The fluid losses within a pump may be divided as follows:

a Velocity head due to plunger velocity, varying from zero to the maximum above cited. This loss may be ignored however, since with well rounded plunger ends and rounded water passages, the accelerating head of the fluid column during the first half of the stroke is conserved by its retarding force during the second half.

b Friction head due to surface contact. As the main parts of a pump are comparatively large, the velocities are low: and the lengths of contact being short, this friction-head is equal to a velocity-head for only about 50 diameter lengths, and becomes so small as to be negligible.

c Velocity head through the valves. This, whatever its amount, is a total loss because the energy of the issuing streams is destroyed in eddies as it enters the large valve or pump chambers. To keep this head low is the purpose of the specification stating that the valve area shall exceed the plunger area by a certain amount.

8 Let us assume that valve area means valve-seat area, and pass on to the study of the valve. A pump valve consists essentially of three elements (*a*) a fixed seat, (*b*) a movable valve, (*c*) a spring. The most important of these is the spring, and yet on this point all specifications are silent. Is this because the writer of the specification knows nothing about the subject? In a general way, it is obvious that a spring may be so stiff that on the suction stroke, where only atmospheric pressure is available, the valve will not open at all; or it may be so light that it will nearly float in its place and will close only with the return stroke of the plunger. Between these two extremes, is there not an ascertainable strength of spring which will

allow the valve to close promptly without shock and yet require for lifting force but a small percentage of the total pressure in the pump? So far as I am aware, this problem has not been stated and solved in any publication, but is left for each pump builder and user.

9 The pressure of the spring per square inch of the inside seat area seems to me to be the force that causes the rate of flow of the water through the valve. In my experiments of 1875 (see Vol. 10 of Transactions) with a Cornish double-beat valve, this hypothesis did not hold, that is, the velocity through the valve was from 60 to 90 per cent greater than that due to the pressure of the valve: in other words, the valve did not rise as high as theory would demand,

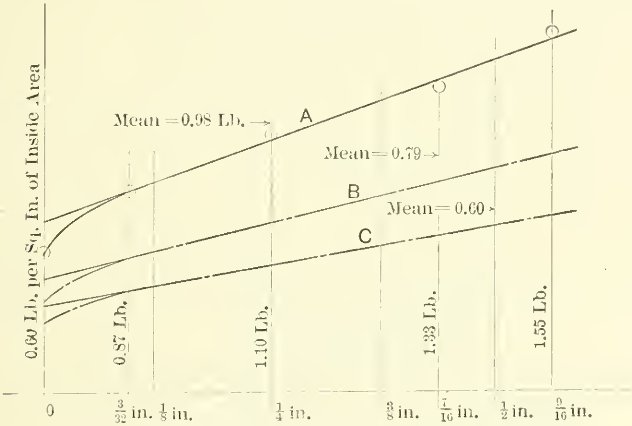

FIG. 1 DIAGRAM SHOWING VARIATIONS OF TENSION

LINE A IS THE ACTUAL TENSION OF A SPRING AT VARIOUS POINTS OF LIFT. LINES B AND C SHOW ESTIMATED TENSIONS AT DIFFERENT LIFTS WITH AN INITIAL TENSION OF 0.4 LB. AND 0.3 LB.

but I think the deviation may be attributed to the large curvature given the upper passage. In extensive experiments recently made by the Bethlehem Steel Company with a large flat-hinge, or flap, valve to be used in the Baltimore sewage pumps, the hypothesis held very well at the beginning of the lift and fell off only about 10 per cent at full lift. These experiments also confirmed the Providence experiments in that the varying lift of the valve follows closely the varying velocities of the plunger, except as it is modified by increased weight or spring tension.

10 I shall therefore assume that in a flat rubber pump valve held down by a spring (a) the velocity of the water is that due to pressure

per square inch of the inside valve area, (*b*) the area of discharge is the net circumference of the inside of the seat multiplied by the lift.

11 The well-known formula for the velocity of flow in feet per second is

$$V = 8.025 \sqrt{h} \qquad [1]$$

(*a*) where *h* is the head of water in feet. As 2.31 ft. of water 1 sq. in. in area weighs 1 lb., the formula can be changed to

$$V = 12.23 \sqrt{p} \qquad [2]$$

(*b*) where *p* is the pressure of spring per square inch of inside area

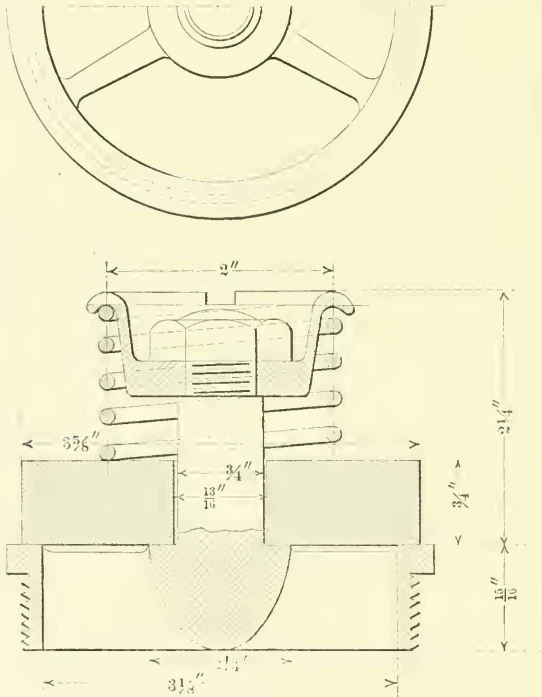

Fig. 2 Section of a Standard Make of Pump Valve

FREE LENGTH OF SPRING IS $1\frac{9}{16}$ IN., NO. 12 B. W. G. SPRING BRASS

of valve. Tables 1 and 2, computed from Formula 2, may be convenient in studying this subject.

12 *Springs.* The springs in common use vary from 0.40 to 0.60 lb. per sq. in. of inside valve area at the beginning of the lift, and as they are comparatively short (about 1⅝ in. closed), they tighten up

TABLE 1 CONVERSION OF VELOCITY INTO PRESSURE

Velocity Ft. per Sec.	Pressure Pounds per Sq. In.	Velocity Ft. per Sec.	Pressure Pounds per Sq. In.	Velocity Ft. per Sec.	Pressure Pounds per Sq. In.
4	0.107	8	0.430	12	0.967
5	0.168	9	0.544	13	1.135
6	0.242	10	0.672	14	1.317
7	0.329	11	0.813	15	1.512

TABLE 2 CONVERSION OF PRESSURE INTO VELOCITY

Pounds Pressure	Velocity Ft. per Sec.	Pounds Pressure	Velocity Ft. per Sec.	Pounds Pressure	Velocity Ft. per Sec.	Pounds Pressure	Velocity Ft. per Sec.
0.15	4.74	0.50	8.65	0.85	11.27	1.40	14.47
0.20	5.47	0.55	9.07	0.90	11.60	1.50	14.98
0.25	6.11	0.60	9.47	0.95	11.92	1.60	15.47
0.30	6.70	0.65	9.86	1.00	12.23	1.70	15.94
0.35	7.23	0.70	10.23	1.10	12.82	1.80	16.40
0.40	7.73	0.75	10.59	1.20	13.39	1.90	16.85
0.45	8.20	0.80	10.94	1.30	13.94	2.00	17.29

TABLE 3 RATIO OF PRESSURES, VELOCITIES, AND LIFT OF VALVE, LINE A

Lift Inches	Tension Pounds per Sq. In.	Velocity Ft. per Sec.
At Start	0.60	9.47
$\frac{3}{32}$	0.87	11.40
$\frac{1}{4}$	1.10	12.82
$\frac{7}{16}$	1.33	14.10
$\frac{9}{16}$	1.55	15.23

TABLE 4 RATIO OF PRESSURES, VELOCITIES AND LIFT OF VALVE, LINE B

Lift Inches	Tension Pounds per Sq. In.	Velocity Ft. per Sec.
At Start	0.40	7.74
$\frac{3}{32}$	0.58	9.31
$\frac{1}{4}$	0.73	10.47
$\frac{7}{16}$	0.88	11.51
$\frac{9}{16}$	1.03	12.41

TABLE 5 RATIO OF PRESSURES, VELOCITIES AND LIFT OF VALVE, LINE C

Lift Inches	Tension Pounds per Sq. In.	Velocity Ft. per Sec.
At Start	0.30	6.70
$\frac{3}{32}$	0.44	8.07
$\frac{1}{4}$	0.55	9.07
$\frac{7}{16}$	0.66	9.97
$\frac{9}{16}$	0.77	10.83

rapidly as the valve rises. Fig.1, Line A, illustrates this rate of increase taken from a new spring. The apparently needlessly stiff springs are used (*a*) to provide against the relaxation sure to occur with all bronze springs; (*b*) to allow for the lengthening of the spring as the rubber valve wears away.

13 Fig. 2 shows a standard pump valve used by a prominent builder. These valves run from $2\frac{1}{2}$ in. to $3\frac{3}{4}$ in. inside diameter. Table 3 is made up from Fig. 1, with the velocities computed by Formula 2. A larger lift than $\frac{8}{16}$ in. is not generally allowed for, as the valve is not expected to rise higher or even as high as this, and considering the increased tension of the spring one would not expect it.

14 *Other spring tensions.* In Fig. 1, Line A represents the actual tension of a spring at various points of lift. If the same type of spring were made of smaller wire, its varying tensions at different lifts would be proportional to the initial tension. Lines B and C show these estimated tensions at different lifts with an initial tension of 0.40 lb. and 0.30 lb., respectively; Tables 4 and 5 give the tension at these lifts, together with the velocities corresponding thereto.

15 *Valve Lift.* If it is true that the spring tension governs the velocity of water through the valve, we can readily find the lift of a valve under specified conditions. Knowing the volume of water passing through the valve per second, the inside net circumference multiplied by its lift and the velocity must equal the volume. By formula, $P \times V_m = C \times L \times v_m \times N$, where

P = plunger area in square inches.
V_m = maximum velocity of plunger in feet per second; which is $1.60 \times$ the mean velocity.
C = net circumference of valve seat, inches.
L = lift of valve, inches.
v_m = maximum velocity of water at Lift L, found by aid of the diagram, Fig. 1.
N = number of valves.

or

$$L = \frac{P \times V_m}{C\ N\ v_m}$$

Contractions at sharp corners and angular turns make this calculation inexact, but the method will be found correct enough for the comparisons in this paper, and is the only practical method in the present state of knowledge on this subject.

16 *Comparisons of valve areas and springs.* To illustrate my views, let us take the case of a vertical triple-expansion crank and flywheel pumping engine, having each plunger 34 in. in diameter by 60 in. stroke, making 25 r.p.m.—practically a 25,000,000-gal. engine. Plunger travel = 4.167 ft. per sec., and maximum plunger velocity = 6.67 ft. per sec. Assume the pump valve to be $3\frac{3}{4}$ in. inside diameter with 5 ribs, leaving a net area of 8 sq. in., and a net circumference of 10.53 in. The theoretical lift of this valve, to give the same area on the circumference as through the ribs, would be 0.76 in. Let us assume a valve-seat area equal to 150 per cent of the plunger area and an initial spring tension of 0.60 lb., and ascertain the number of valves, their lift, velocities at various points and loss of efficiencies. Then let us make the same calculations for a valve-seat area equal to the plunger area, with an initial spring tension of (*a*) 0.40 lb. per sq. in.; (*b*) 0.30 lb. per sq. in. The results are given in Table 6.

TABLE 6 LOSS OF EFFICIENCIES, ETC.

Initial Spring Pressure Pounds	Valve Seat Area Per Cent	Number of Valves	Lift of Valves Inches	Velocities in Feet per Second			Loss of Efficiency Per Cent
				Plunger	Valve Seat	Valve	
1	2	3	4	5	6	7	8
0.60	150	170	$\frac{1}{4}$	0–6.67	0–4.44	9.47–12.82	2.45
0.40	100	114	$\frac{7}{16}$	0–6.67	0–6.57	7.74–11.51	1.97
0.30	100	114	$\frac{1}{2}$	0–6.67	0–6.57	6.70–10.37	1.50

17 *Explanations.* Column 4. The plunger area (908 sq. in.) multiplied by its maximum velocity (6.67 ft. per sec.) must equal number of valves (170 or 114) multiplied by the net circumference (10.53 in.), its lift L, and the maximum velocity at its highest lift. This is a trial process, but easily found after one or two trials. Taking the first case, we would have

$$908 \times 6.67 = 170 \times 10.53 \times 12.82, \text{ or } L = 0.264 \text{ in.}$$

Second case:

$$908 \times 6.67 = 114 \times 10.53 \times L \times 11.51, \text{ or } L = 0.438 \text{ in.}$$

Third case:

$$908 \times 6.67 = 114 \times 10.53 \times L \times 10.37, \text{ or } L = 0.50 \text{ in.}$$

18 Column 5. While the crank velocity may ordinarily be taken as the maximum plunger velocity with a connecting rod five times the crank, its maximum velocity is 1.019 times that of the crank or, maximum velocity = $5 \times 3.1416 \times 25 \times 1.019 \div 60 =$ 6.67 ft. per sec. We can also take the mean travel of the plunger and multiply it by 1.60 to find the maximum velocity.

19 Column 6 is self-evident.

20 Column 7. These velocities are obtained from Tables 3 to 5 and Fig. 1, and were computed in the manner already described.

21 Column 8. To get an expression for the effect of strong *vs.* light springs upon the economical working of a pump, I have assumed a pump working under a total head of 80 lb. per sq. in. and computed the *mean* pressure required to operate the valve, calling this ratio of pressures its loss of efficiency.

22 A careful examination of the diagram of spring compression, Fig. 1, shows that at the beginning of the lift the spring did not assume its full uniform resistance. It took nearly $\frac{3}{32}$ in. of motion to tighten it uniformly. I think this is due to the fact that these single coil-wound springs are always a little stiffer on one side than the other, thus canting the valve to an oblique position to conform itself to the center line of resistance of the spring. I have taken as mean pressures of the springs slightly more than the mean of the two extreme positions, because the times during which the different pressures prevail are not equal. Mean pressures were taken as follows:

Case A, maximum tension = 1.10 lb. at $\frac{1}{4}$-in. lift, mean pressure = 0.98 lb..

Case B, maximum tension = 0.94 lb. at $\frac{7}{16}$-in. lift, mean pressure = 0.79 lb.

Case C, maximum tension = 0.72 lb. at $\frac{1}{2}$-in. lift, mean pressure equals, 0.60 lb.

As this mean pressure exists during both strokes, it must be multiplied by two to find its ratio to the effective head of 80 lb., operating only during one stroke. Thus the values given in Column 8 are found.

23 *Discussion and Recommendation.* A study of the figures given in Table 6 shows that the proper place to look for "loss of head" in a pump is in the spring tension, and not in the valve-seat area. As long as the maximum velocity through the seat does not exceed that through the valve, it does not add to the total loss of head. The only

reason for having a large number of pump valves and a large inside diameter is to keep the lift down, basing judgment on the number of reversals per minute.

24 We have seen that a $3\frac{3}{4}$-in. valve, having a net area of 8 sq. in., needs 0.76 in. lift to give the same area at the circumference as through the seat. If there were no rib obstruction, 25 per cent of the diameter of a circle gives the height to which a valve must lift to give a circumferential opening equal to its area. Because of the ribs, we need but 20 per cent of the diameter for the lift; and with the lightest spring *C*, a maximum lift of $\frac{1}{2}$ in. or 13 per cent of the diameter was sufficient to discharge the required volume of water. It will be good construction to limit the lift of a pump valve of this type to, say, 15 per cent of its internal seat diameter. The spring will not allow it to rise to that height, but it is a safe limit for a stop.

25 The place to begin the study of proportions of a pump is at the *spring* of the valve. *Make* a sample spring of such diameter and length and strength as you may think desirable, and by *experiment* construct a diagram of its rate of compression, as in Fig. 1. Now you can find the maximum velocity at an assumed lift and proceed in the manner already pointed out. The spring would be improved, that is, it would not tighten up so rapidly when compressed, if it could be made somewhat longer than present practice, but this is not practicable, as it would enlarge the valve chamber, where the valve-cage design is used.

26 The largest and weakest castings within a pumping engine are the valve chambers and anything that can be done to reduce them to the minimum size permissible is good engineering. I think the line of study I have pursued will indicate that the total valve-seat area in this type of engine need not be more than the plunger area. That rule, if adopted, would reduce the diameter of the valve chambers to an appreciable extent, probably 10 per cent, and this is well worth saving.

27 The number of valves saved by the construction recommended (about 33 per cent) is also worth saving. No loss whatever would be entailed and a part of the money saved could be expended in making a better spring. I would make the spring of steel, if possible, oil-tempered, and protected against corrosion by copper electroplating. Then I would have all springs tested and brought to a like tension under a rigid specification. With these improvements I believe that a little better pumping engine than we now have could be obtained at a little smaller cost.

A REPORT ON CAST-IRON TEST BARS

By A. F. Nagle, Bethlehem, Pa.
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In machinery castings as well as in cast pipes, separate bars are cast and subjected to tensile or transverse stress to the breaking point, these results being used as evidence of compliance with the contract specifications. The writer has examined a large number of such test bars for castings used in the Baltimore sewage pumps and here reports the results of this examination and study. Perhaps the most important conclusion is that the test bar is not to be regarded with too much confidence as indicative of the exact strength of the casting.

2 All transverse bars were nominally 2 in. by 1 in. by 24 in. centers. They were cast from two patterns in one mold, made in the same kind of sand as the main casting. The flask was inclined about 30 deg. There was but one gate for the two bars, with suitable risers. The iron for the bars was poured from a small ladle of iron taken as near as might be from the middle of the pour of the main casting. The breaking loads were corrected for varying dimensions of the bars by the formula $W' = \frac{Wbd^2}{2}$, where b and d are the actual dimension, W the actual breaking load, and W' the corrected load or weight. These results are used throughout this paper. The deflections were not corrected.

3 The tensile bars, $1\frac{5}{8}$ in. by 6 in., were cast upright in the same mold as the main casting, within three or four inches thereof, and connected by an upper and lower gate. The tensile bars were turned to $1\frac{1}{2}$ in. diameter and threaded, and the middle portion reduced to 1.129 in. diameter, which is equal to 1 sq. in. area. Table 1 gives the results of the chemical analysis of the several bars tested.

4 From August 5, 1907 to April 4, 1908 there were made 67 *single* tensile bars and the same number of pairs of transverse bars, and the

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TABLE 1 ANALYSIS OF CAST-IRON TEST BARS

Bars used in I. P. Bed Plate Cast November 21, 1907, and I. P. Frame, Cast November 26, 1907 for Baltimore Sewage Pumps

Date Cast	Total Carbon	Graphite Carbon	Combined Carbon	Manganese	Phosphorus	Sulphur	Silicon	Tensile Strain	Transverse Load	Deflection
Nov. 21, 1907.....	3.580	2.830	0.75	0.79	0.485	0.081	1.59	24,900	2440	0.49
Nov. 26, 1907......	3.396	2.736	0.66	0.38	0.459	0.124	1.91	22,000	2075	0.40

average of the latter was used in this record. From April 4 to December 19, 1908 there were made 91 *pairs* of tensile bars and an equal number of pairs of transverse bars, and each piece of the pair is recorded, instead of the average.

5 Of these 249 tensile bars and their corresponding transverse bars, 32 sets—26 flat and 6 round—were rejected for defects due to blow-holes and four tensile bars were too hard to bear threading, but the companion piece was used in this record.

6 Of the 217 specimens here recorded, 42 are designated as abnormal, that is, the ratio between the tensile and the transverse bars was either considerably greater or smaller than the average.

7 By referring to Table 2, it will be seen that of the 175 specimens of cast iron running from 20,000 to 30,000 lb. tensile strength, the ratio of tensile to breaking loads is practically 10 to 1 and the deflection 0.45 in.

TABLE 2 COMPARISON OF CAST-IRON TEST BARS

Number of Specimens	Limit of Breaking Load of Transverse Bars	Breaking Loads Pounds		Deflection Inches	Ratio of Tensile to Transverse
		Transverse	Tensile		
29	2000 to 2200	2065	21,630	0.43	10.47 to 1
36	2200 to 2400	2289	22,940	0.45	10.02 to 1
51	2400 to 2600	2523	24,880	0.47	9.86 to 1
43	2600 to 2800	2756	26,500	0.49	9.61 to 1
16	2800 to 3000	2894	28,460	0.49	9.83 to 1
175	Averages	2383	23,732	0.45	9.96 to 1

Note.—Transverse Bars, rough 2 in. by 1 in. by 24 in. centers; tensile bars, turned 1.129 in. diameter (1 sq. in. area).

8 Table 3 gives 25 abnormal cases where this average ratio is as high as 12.56 to 1 with a deflection of 0.43 in.; also 17 abnormal cases where this average ratio is as low as 7.91 to 1 with a deflection of 0.44 in. And yet the average of both normal and abnormal bars was again very nearly 10 to 1—10.07 to 1.

9 Breaking loads, presumably alike, varied in pairs of transverse bars, and also in pairs of tensile bars, as follows:

Out of 65 pairs of flat or transverse bars,

14, or 22 per cent, average variation 18 per cent.

TABLE 3 COMPARISON OF CAST-IRON TEST BARS

Abnormal Results

Number of Specimens	Limit of Breaking Load of Transverse Bars	Breaking Loads Pounds		Deflection inches	Rato of Tensile to Transverse
		Transverse	Tensile		
		Above 10 to 1 ratio			
10	2000 to 2200	2088	27,143	0.41	12.95 to 1
10	2200 to 2400	2294	28,530	0.43	12.44 to 1
4	2400 to 2600	2436	29,600	0.49	12.15 to 1
0	2600 to 2800	00	00		
1	2800 to 3000	2890	34,000	0.45	11.76 to 1
25	Averages	2258	28,365	0.43	12.56 to 1
		Below 10 to 1 ratio			
1	2000 to 2200	2105	17,600	0.50	8.36 to 1
4	2200 to 2400	2359	18,825	0.41	7.98 to 1
7	2400 to 2600	2487	18,814	0.43	7.57 to 1
3	2600 to 2800	2656	21,230	0.45	8.00 to 1
2	2800 to 3000	2969	24,500	0.47	8.25 to 1
17	Averages	2521	19,954	0.44	7.91 to 1

17, or 26 per cent average variation 5.4 per cent.

34, or 52 per cent average variation less than 2 per cent.

Out of 65 pairs of round or tensile bars,

22, or 34 per cent average variation 15 per cent.

20, or 31 per cent average variation 5.5 per cent.

23, or 35 per cent average variation less than 2 per cent.

61 other pairs of flat bars, which had only one companion tensile bar, varied in about the same ratios.

10 Two special flat bars and two special round bars, cast in one mold, one gate and at one pour, varied as follows:

2 flat bars, 12 per cent.
2 round bars, 7 per cent.

11 In order to get some more definite information on these variations, if possible, I had a pair of transverse and a pair of tensile bars made and cast in the same mold, and while the average ratio of tensile to transverse strength was again nearly 10 to 1, as shown in Table 4, the same type of bars again varied 12 per cent and 7 per cent respectively as shown in Par. 10.

12 I have no satisfactory explanation for the great variations in these test bars, and we can only accept the fact that mathematical uniformity in strength of cast-iron bars is not found in the present state of the art. To anyone questioning the results I can only say from my own knowledge of the circumstances that the personal equation did not enter into them.

TABLE 4 COMPARISON OF CAST-IRON TEST BARS

SPECIAL, TWO SETS CAST IN SAME MOLD AT SAME TIME

Number of Specimens	Limit of Breaking Load of Transverse Bars	Breaking Loads Pounds		Deflection Inches	Ratio of Tensile to Transverse
		Transverse	Tensile		
1		2350	23,000	0.50	9.79 to 1
1		2100	21,470	0.45	10.21 to 1
2	Average	2225	22,235	0.47	10.04 to 1
217	All Averages	2380	23,970	0.45	10.07 to 1

13 Careful observation of broken bars did not show that the so-called "skin of the metal" was of any appreciable thickness, and the metal was remarkably homogeneous throughout. The tensile bars being turned, the skin, if there were any, of course disappeared. It is my opinion that the skin adds practically nothing to the strength in either transverse or tensile bars, other causes, though obscure, producing far greater deviations.

14 Although many castings were condemned for physical defects, such as blow-holes, shrink-holes, sand-washes, and shifting of cores, not a single case of cold-shut was discovered. This is in marked contrast with the writer's experience on similar work in other foun-

dries. Excepting a number of steam valves, which were of iron too soft for their purpose, but one large casting, a discharge air chamber weighing 16,000 lb., was condemned for being of unsatisfactory iron. In this case the iron was coarse-grained and brittle, and was required to stand at least 23,000 to 24,000 lb. To remove all doubt that the test bars were truly representative of the iron in the main casting, two tensile bars were cut out of a large flange, which had been at the bottom of the mold. These, from the most favored part of the casting, as will be seen, stood but about 17,350 lb.; 90 per cent of that revealed by the test bars. In this case there was a remarkable agreement among these pairs of bars.

15 It may be interesting to apply these results to the formula for the strength of cast-iron beams subjected to similar stress. The commonly used formula (Kent, page 268) is

$$R = \frac{3\,Pl}{2\,bd^2}$$

TABLE 5 TEST BARS FROM CONDEMNED CASTING

Breaking Loads Pounds		Deflection Inches
Transverse	Tensile	
1,968	19,800	0.35
2,019	19,000	0.50
	Cut out of flange	
	17,000	
	17,700	

where R is called the modulus of rupture, or stress per square inch of extreme fiber.

P = load at center.
l = length in inches between supports.
b and d = breadth and depth, respectively in inches.

Making the proper substitutions, we have $R = \frac{3 \times 2380 \times 24}{2 \times 2 \times 1 \times 1}$, or R = 42,840 lb. This is not the correct figure, however, for the extreme fiber stress: we know this cannot exceed the tensile strength, which we have found to be 23,732 lb.

16 I think it is better to use D. K. Clark's formula, given on page 507 of his Engineers' Tables, etc., $S = \frac{Wl}{1.155\,bd^2}$, where S = extreme

fiber stress, or tensile strength. If we use the tensile strength found in these tests as 23,732 lb., the breaking load W would become $\frac{23{,}732 \times 1.155 \times 2 \times 1}{24} = 2284$ lb., the actual breaking load being 2383 lb. As this is within 4.3 per cent of the average found in these tests, this formula, using the tensile strength for the extreme fiber stress, seems to me to be the more intelligible and dispenses with the "coefficient of rupture."

17 "Mr. Barlow found by experiment that for 1-in. square bars of cast iron, the breaking weight in tons [2240 lb., I presume] was expressed by the formula $W = \frac{bd^2}{l} \times 13.6$, and Mr. Robert Stephenson arrived by experiment at exactly the same coefficient." Clark, page 561.

TABLE 6 CIRCULAR TEST BARS CAST IN VERTICAL DRY-SAND MOLD

Bar Mark	Breaking Loads Pounds		Deflection Inches	Value of W by Formula Pounds	Original Diameter Inches
	Transverse	Tensile			
H	3344	23,070	0.15	2948	1.305
H	3344	23,754	0.15	3036	1.305
X	3026	24,670	0.12	3153	1.300
1	2	3	4	5	6

18 If we should substitute the value for W found in these tests we would have W, or $\frac{2383}{2240}$, $= 1.064$ tons $= \frac{2 \times 1}{24} \times$ a constant, or, constant = 12.77, which is within 7 per cent of the coefficients found by Barlow and Stephenson.

19 Since the foregoing was written I have had the opportunity to observe two circular test bars nominally $1\frac{1}{4}$ in. in diameter by 15 in. long, with 12-in. centers. These bars were cast from two patterns in one vertical dry-sand mold and poured from a small ladle, first one and then the other, with the results shown in Table 6.

20 The tensile bars were taken from the bottom end of the broken test bar, but I do not know whether H or X was poured first. The first tensile bar H had a small air hole, which being corrected for added 7 per cent to its tensile strength, and this is also given in the table. A second bar was then turned up from the immediate joining piece with the result recorded first in the table. The turned bars

were 0.937 in. in diameter. Column 6 gives the original diameter. Column 2 was found by reducing the actual breaking loads in the ratio of the cubes of the diameters, and Column 3 was reduced to the square inch area. Why the transverse breaking loads should vary 10 per cent and the tensile bars 4 to 7 per cent the opposite way, a total variation of 14 to 17 per cent, I leave to the reflection of the reader. If we apply Clark's formula for the breaking weights for circular bars, $W = \frac{0.7854 \times d^3 \times S}{l}$ we find the values given in Column 5.

21 In this age of economic production, the cost of these turned tensile bars is frequently objected to by the manufacturer. While blowholes seem to be more frequent in flat transverse bars than in round attached tensile bars, the latter seem liable to a greater abnormal hardness, for which I have no explanation. Some indication of the toughness of cast iron can be seen in its deflection, which is not revealed in a direct tensile pull. I should, therefore, be satisfied with two or three transverse test bars 2 in. by 1 in. by 24 in. centers, and a deflection record poured, as near as may be, from the middle of the pour of the main casting, as giving a fair indication of the iron in the main casting, but mathematical exactness cannot be looked for as yet.

22 If we wish to know approximately the corresponding tensile strength of the iron, we can multiply the breaking load of the 2 in. by 1 in. by 24 in. flat bar by 10. If the test bar is of $1\frac{1}{4}$-in. diameter by 12-in. centers, its breaking load should be multiplied by 8, to obtain the approximate tensile strength. The general rule seems to be, that where both flat bars agree in breaking loads, the tensile strength is 10 to 1 of the breaking load, but where they differ, the 10 to 1 ratio does not hold. A better practice, therefore, might be to cast three round transverse bars and accept the two that agree, if each is round, as a fair sample of the iron, dispensing with the tensile bars. This concession to the manufacturer, I believe, would entail not only no loss to the city's interests, but a positive gain.

TESTS ON A VENTURI METER FOR BOILER FEED

By Prof. C. M. Allen, Worcester, Mass.

Member of the Society

A reliable and accurate hot-water meter has been in demand for a good many years. The principle of most of the cold-water meters, where there are moving parts in the water, is not at all adaptable for hot-water work. A hot-water meter for boiler-feed purposes must stand not only the variation in temperature but also considerable variation in pressure, and quite often it has to stand a certain amount of water-hammer, this depending somewhat upon the style and condition of pump used. The Venturi meter, having no moving parts to get out of order and being of material which will stand the ordinary corrosive effects, should make a reliable hot-water meter.

2 The object of these tests was to determine the accuracy of a Venturi meter to be used for measuring boiler feed under a great variety of conditions. The plan was to make a complete series of tests upon a small Venturi meter under all the probable conditions that would ever be met in boiler room practice. The tests were made under varying temperatures and velocities; under varying pressures, intermittent and steady; using a triplex power pump in good condition, and with one plunger out of commission, a duplex steam pump in good condition and in poor condition, and an injector.

3 The meter was installed in the steam engineering laboratory of the Worcester Polytechnic Institute and set up the way most convenient not only for weighing the water passing through the meter, but also for heating the water before it went through the meter, and pumping it in in various ways. The meter used was built by the Builders' Iron Foundry of Providence, R. I., and is what is ordinarily called a 2-in. meter, the upstream and downstream ends being 2 in. in diameter and the throat $\frac{3}{4}$ in. in diameter. The main part of the meter is of cast iron and the internal portions are lined with brass. Surrounding the upstream end and throat are annular chambers between

To be presented at a meeting of The American Society of Mechanical Engineers. All papers subject to revision.

the brass sleeve and the iron casing. Six holes are drilled through the brass lining into these annular chambers at about equal distances around the circumference, in order to give the actual pressure heads in the meter at both throat and upstream end. From the outside of these annular chambers were pipe connections to a manometer tube which consisted of a glass U-tube containing mercury. There were the necessary valves and pet-cocks to manipulate the meter, blowing out the air whenever it accumulated. The general layout of the apparatus is shown in Fig. 1.

4 The apparatus was set up so that the meter could be supplied from a $1\frac{1}{4}$-in. metropolitan injector, a $4\frac{1}{2}$ in. by $2\frac{3}{4}$ in. by 4 in. duplex pump or 4 in. by $5\frac{3}{4}$ in. triplex power pump; or from a pressure tank supplied from the city mains or by a large duplex pump. These pumps were arranged to take their suction from a pit 12 ft. long, 6 ft. wide and 4 ft. deep, directly beneath the Venturi meter. A 1-in. steam line was put in to heat the water. There being about 300 cu. ft. in the supply pit, a very even temperature could be maintained. In order to keep the discharge from the pumps constant, a suction well was supplied, kept at constant level by an additional pump from the main pit. The discharge from all the pumps used was carried up a vertical 2-in. pipe, at the top of which was an air chamber 4 in. in diameter and 3 ft. long, with a valve so inserted that it might be cut out whenever desired. From this vertical pipe ran a line containing the Venturi meter, a thermometer-well for determining temperatures, and a valve for throttling water in order to get any desired pressure. At the end of this line was a swinging end that discharged into either of two 5000-lb. weighing tanks.

5 The first tests were made with cold water in order to determine the coefficient. These were made with steady pressure, securing a very constant flow. Water was run through the meter until the conditions had become constant. One tank was weighed while the water was being discharged into the other. The tests were started by diverting the discharge into the weighing tank and taking the time. Readings of the Venturi meter were taken every thirty seconds for low velocities and every minute for higher. The tests were ended by diverting the discharge into the other tank, taking the time and weighing.

6 When hot water tests were made, it was found that a certain amount of water evaporated; evaporation tests were therefore made, which proved this amount to be a negligible quantity.

7 In order to compare the workings of the meter under the various

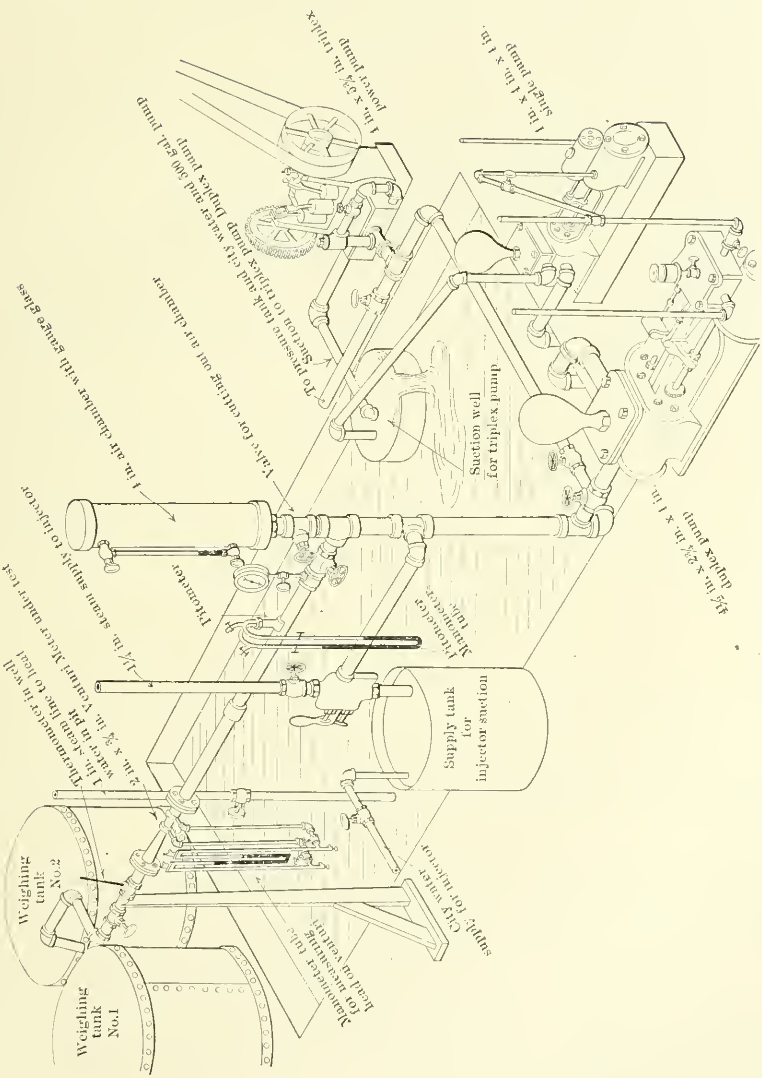

Fig. 1 Layout of Apparatus, Venturi Meter Tests

conditions, it was decided to determine the coefficients for this meter under these conditions. The discharge of the Venturi meter was figured from the regular formula, using a coefficient of one, and the actual weight obtained from the weighing tanks was divided by this value to obtain the real coefficient.

8 The following temperatures were used during the tests: 80 deg., 120 deg., 140 deg., and 180 deg. fahr. Water for these tests was supplied by the triplex power pump with different velocities through the meter. Tests were made at 140 deg. with and without the air chamber, the water being furnished by the triplex power pump; then at 140 deg. with one plunger of the triplex pump disconnected so as to produce fluctuations in the velocity and pressure of the water supplied to the meter.

9 In order to duplicate more nearly the conditions of boiler feed, an air chamber and check valve were placed in the pipe line in the downstream side of the Venturi meter (not shown in Fig. 1). Because of the air chamber at this end the pump fluctuations could pass through the meter to a much more marked degree than if the discharge was merely throttled by a valve. Under these conditions tests were run with water supplied by the injector, taking suction from a special supply tank; with the injector, however, the temperature of the water of necessity varied with the velocity through the meter.

CONCLUSIONS

10 The chief difficulty encountered in making this series of tests was in getting the true average readings of the manometer. With the higher velocities through the meter, the fluctuations could be easily dampened by closing the valves to the manometer tube, but with the lower velocities any error in reading was so large in proportion to the entire head as to make a considerable difference in results. It may be said, then, that the meter is not accurate for velocities of less than 10 ft. per sec. in the throat of the meter, which corresponds to a discharge of 0.03 cu. ft. per sec., or about 6140 lb. per hr., so that this meter would be best adapted for measuring water for a boiler plant of above 200 h.p. The coefficients are materially lower below 0.03 cu. ft. per sec. The principal feature shown by the cooler water tests (80 deg. fahr.) is the low value of the coefficients of the meter, the average, excepting the values for velocities below 10 ft. per sec., being 0.942. This coefficient might have been expected, however, as in a small meter the ratio of area of cross section to surface is much lower.

11 These experiments clearly show that the meter is as accurate for hot water as for cold. The maximum error in discharge, as figured from manometer deflections using the mean coefficients for that temperature, is as follows: 80 deg., 1.39 per cent; 120 deg., 1.5 per cent; 140 deg., 1.9 per cent; 180 deg., 0.82 per cent. The average error is well within 1 per cent.

12 Of the pumps tried with the meter, the triplex gave by far the best results, and it may be confidently stated that the Venturi feedwater meter would give very satisfactory results in a plant using the power pump. Even with one plunger disconnected, the maximum variation was only 2.4 per cent.

13 In tests with the injector, the weighed calculation from the Venturi formula, using the mean coefficient, shows variations from actual weight of 3 per cent. The average error is inside 2 per cent.

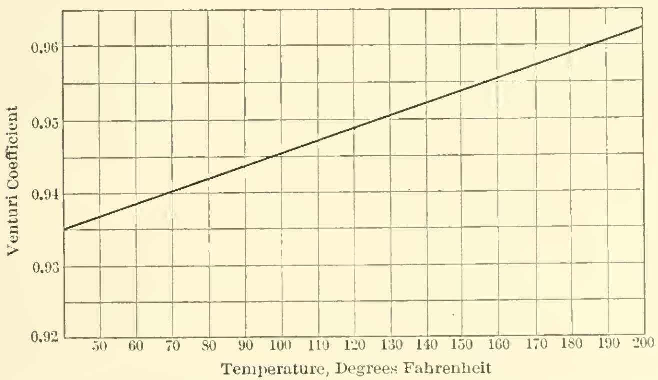

Fig. 2 Curve Showing Variation of Venturi Coefficient with Rise in Temperature

14 The results from 4½ in. by 2¾ in. by 4 in. duplex pump show up better than might be expected as this pump was in very poor condition, the piston rods being so worn that the pump took air through the stuffing boxes at the water end.

15 These tests represent the worst conditions which would be met with in boiler feed. The pump would start building up pressure, then pause until the pressure had fallen. The check valve, which was located only about 6 in. downstream of the Venturi meter, was opening and closing constantly. For a discharge of more than 0.03 to 0.04 cu. ft. per sec., the coefficients were very consistent.

16 It must be remembered in considering these tests that the Ven-

turi meter itself probably worked more accurately than the tests would indicate, as every change in velocity through the meter is accompanied by its corresponding change in head on throat and upstream end, and that a continuous recording device attached to the meter would probably cut down the error considerably. It is the opinion of the experimenters that the Venturi meter is a very reliable form of hot-water meter, provided the proper size is used.

17 These tests were conducted for the most part by George Y. Lancaster, a post-graduate student in mechanical engineering at Worcester Polytechnic Institute, and these results are taken from a thesis submitted by him.

THE DESIGN OF CURVED MACHINE MEMBERS UNDER ECCENTRIC LOAD

By Prof. Walter Rautenstrauch, New York

Member of the Society

Machine members, such as frames for punches, shears and riveters, hooks and the like, when subjected to load are generally supposed to behave like beams originally straight and subjected to the same conditions. The usual analysis applied to such beams in determining the proportions required to withstand safely a given stress assumes that the maximum tensile stress at a in Fig. 1 = load considered as uniformly distributed over the section + the stress due to the eccentricity of the load. Symbolically expressed

$$f_t = \frac{W}{A} + \frac{Wle}{I}$$

where

f_t = maximum intensity of tensile stress.
W = load on beam.
A = area of section.
I = eccentricity of loading.
e = distance from gravity axis of section to point under stress f_t.

2 This analysis is unfortunately prevalent in textbooks on the design of machine elements and strength of materials, and has been accepted generally because of long standing. However, it does not agree with the results of experiment on members of this kind; in fact such experimental results are so different from results calculated by this formula that no confidence whatever can be placed in it and safe proportions can be obtained only by the use of a large factor of safety.

3 The writer has recently published[1] the results of a series of

[1] American Machinist, October 7, 1909.

To be presented at a meeting of The American Society of Mechanical Engineers. All papers are subject to revision.

experiments which are remarkable in their disagreement with the results obtained by the formula. The crane hook was taken as an example of a beam of this sort and experiments were conducted on ten hooks ranging from two to thirty tons rated capacity. All hooks were furnished by the manufacturers. In Table 1 the results of the experiments are compared with the results by formula.

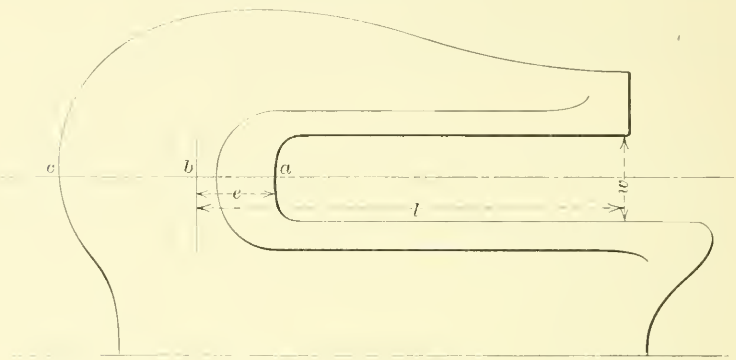

FIG. 1 MACHINE-TOOL FRAME CONSIDERED AS A LOADED BEAM

4 It is very evident that the assumptions on which the above formula is based are not correct, and that machine members designed on this basis have a much smaller factor of safety than is generally supposed. While this has been known in some quarters and attempts have been made to bring about an adjustment, no theory which has been developed seems to fit the case better than that evolved by E.

TABLE 1 COMPARISON OF RESULTS

Description of Hook	Load at Elastic Limit by Test Pounds	Load at Elastic Limit by Standard Formula Pounds
30-ton cast steel	56,000	115,000
20-ton cast steel	30,000	70,000
15-ton cast steel	48,000	145,000
15-ton wrought iron	16,000	73,000
10-ton cast steel	18,000	43,000
10-ton wrought iron	16,000	26.000
5-ton cast steel	18,000	52,300
5-ton wrought iron	14,000	20,800
3-ton cast steel	8,500	14,900
2-ton cast steel	4,700	14,900

S. Andrews and Prof. Karl Pearson of London University. This analysis[1] is deserving of much more attention than it has received, and it is surprising that even some who have had access to it have made the statement that the old theory was sufficiently accurate for the usual case of design. It will not be my purpose to give a complete derivation of the new formula, which has been published elsewhere[1] in complete detail, but rather to show how the results of the analysis may be made directly applicable to design.

5 The investigation referred to gives the following expression for the tensile stress at the most strained point in the principal section of beam:

$$f_t = \frac{W}{A}\left\{\frac{l}{\rho\gamma_2}\left(\frac{1}{\left(1-\frac{e}{\rho}\right)^{\frac{5}{4}}} - \gamma_1\right) + 1\right\}$$

where

f_t = tensile stress at most strained point of section, pounds per square inch.
W = load on hook, pounds.
A = area of section, square inches.
l = distance from load line to gravity axis of section.
ρ = radius of curvature of belly of hook at gravity axis.
e = distance from gravity axis to point of maximum tensile stress.
γ_1 = a function whose value is equal to $\Sigma \dfrac{\dfrac{dA}{\left(1+\frac{y}{\rho}\right)^{\frac{5}{4}}}}{A}$ in which

dA is any differential area of section, a distance y from the gravity axis, Σ denoting the sum of all the operations indicated by the symbols.

γ_2 = a function whose value is equal to $\gamma_1 - \Sigma \dfrac{\dfrac{dA}{\left(1+\frac{y}{\rho}\right)^{\frac{1}{4}}}}{A}$

6 The functions γ_1 and γ_2 are to be found for any section, as shown in Fig. 2. The half-area of the hook is *akhlc*. At any distance y

[1]Technical Series 1, Draper Company's Research Memoirs, 1904.

from b erect an ordinate equal to $\dfrac{d\,g}{\left(1+\dfrac{y}{\rho}\right)^{\frac{5}{4}}}$. Such an ordinate is de. All possible ordinates of this nature determine the curve $aehjc$. Clearly then

$$\gamma_1 = \frac{\text{area } aehjc}{\frac{1}{2}\text{ area of section}}$$

Likewise, if at any distance y from b an ordinate is erected whose

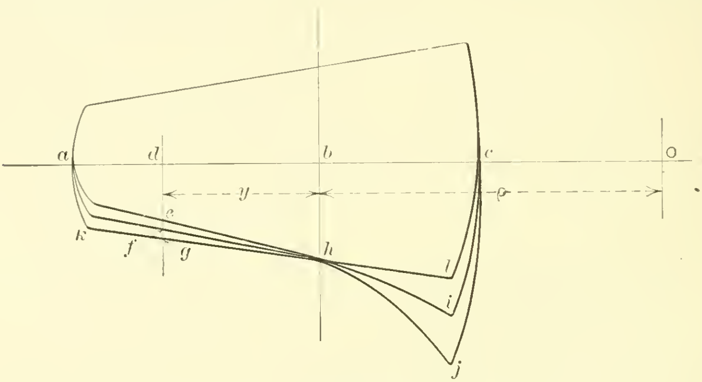

FIG. 2 CROSS-SECTION OF A HOOK

length is $\dfrac{d\,g}{\left(1+\dfrac{y}{\rho}\right)^{\frac{1}{4}}} = df$, all possible ordinates of this nature form the curve $afhic$, and $\gamma_2 = \dfrac{\text{area } aehjc \;-\; \text{area } afhic}{\frac{1}{2}\text{ area of section}}$.

7 The above analysis was applied to each of the hooks tested, with the results recorded in Column 3 of Table 2. An inspection of

TABLE 2 ANALYSIS OF HOOKS TESTED

LOAD AT ELASTIC LIMIT, POUNDS

RATED CAPACITY	30-TON CAST STEEL	20-TON CAST STEEL	15-TON Cast Steel	15-TON Wrought Iron	10-TON Cast Steel	10-TON Wrought Iron	5-TON Cast Steel	5-TON Wrought Iron	3-TON Cast Steel	2-TON Cast Steel
By test	56,000	30,000	48,000	16,000	18,000	16,000	18,000	14,000	8,500	4,700
By standard formula	115,000	70,000	145,000	73,000	43,000	26,000	52,300	20,800	14,900	14,900
By new formula	55,080	29,925	50,570	15,000	16,500	15,000	18,950	14,100	8,600	4,400

this table will show how nearly the analysis of Mr. Andrews and Professor Pearson fits the case and how far from correct are the results from the old formula. The new formula appears then to be based on a correct theory and to be perfectly safe for use in the design of all machine members of this general type.

8 In its present form it is a rather unwieldy instrument in the hands of a designer, but it may be made more applicable to design than might be thought at first. Upon examination it will be seen that the functions γ_1 and γ_2 are constants for all sections of similar form, that is, for all sections the proportions of which may be expressed as a function of some unit of dimension, for example, the radius of curvature. Under the same circumstances the entire expression within the brackets is a constant. The equation for a series of sizes and sections may therefore be written $f_t = \frac{W}{A}K$, or $A = \frac{W}{f_t}K$. The area is a function of the unit squared and therefore we may write $A = C'r^2$, or

$$r = \sqrt{\frac{K}{C'}\frac{W}{f_t}} = C\sqrt{\frac{W}{f_t}}$$

Applying this to the case of a series of hooks ranging from the minimum to the maximum to be manufactured, a standard form of section may be laid out as in Fig. 3, and the constant established. For the hooks tested by the writer the following values for the constant were found:

30-ton hook, cast steel	3.00
30-ton hook, cast steel	3.10
15-ton hook, cast steel	3.23
15-ton hook, wrought iron	4.29
10-ton hook, cast steel	3.49
10-ton hook, wrought iron	3.42
5-ton hook, cast steel	3.12
5-ton hook, wrought iron	3.12
3-ton hook, cast steel	3.78
2-ton hook cast steel	3.74
Average	3.43

9 To make the case representative of present practice let such ratio of proportions be assigned to the section shown in Fig. 3 that $C = 3.4$. The design of a series of wrought iron hooks to sustain

loads of from 2 to 40 tons with a limiting intensity of tensile stress of 30,000 lb. per sq. in. will require the following computations:

$$40\text{-ton hook, } r = 3.4\sqrt{\frac{80000}{30000}} = 5.54$$

$$30\text{-ton hook, } r = 3.4\sqrt{\frac{60000}{30000}} = 4.7$$

$$20\text{-ton hook, } r = 3.4\sqrt{\frac{40000}{30000}} = 3.94$$

$$10\text{-ton hook, } r = 3.4\sqrt{\frac{20000}{30000}} = 2.76$$

$$5\text{-ton hook, } r = 3.4\sqrt{\frac{10000}{30000}} = 1.95$$

$$2\text{-ton hook, } r = 3.4\sqrt{\frac{4000}{30000}} = 1.23$$

10 The proportions obtained above will be for loads giving a maximum stress at the elastic limit of the material. For cast steel differ-

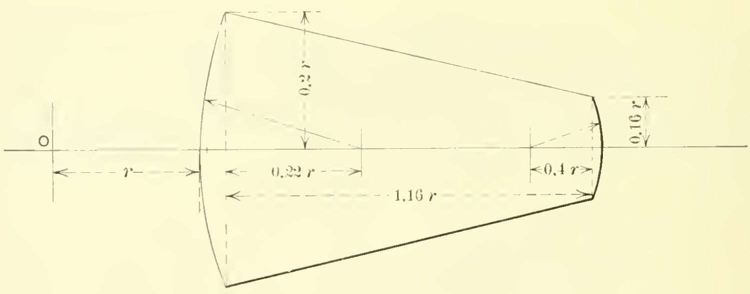

FIG. 3 STANDARD HOOK SECTION

ent values will necessarily be obtained. The establishment of such a standard would lead to a very simple process for the determination of the principal section of a hook for any capacity; the proportions of the shank and other parts of the hook may readily be established on the same basis. The bottom of the hook, being subjected to much wear, cannot of course be proportioned on the basis of the stress analysis. The above standard section selected as an average representative of present practice is not, however, the most economic form of section from the standpoint of equal maximum tensile and compressive stresses. It has been pointed out by Professor Pearson that a

section with such proportions is approximately an isosceles triangle with a radius of curvature of 1.75 of the height. The more nearly this form could be approached the less would be the weight of hook for the same capacity.

11 Professor Goodman[1] points out that for hook sections the functions γ_1 and γ_2 are expressed approximately as follows:

$$\gamma_2 = \frac{ke}{1.2\,\rho^2}$$

$$\gamma_1 = 1 + 1.1\,\gamma_2$$

where k = radius of gyration of the sections, the other symbols being as before noted.

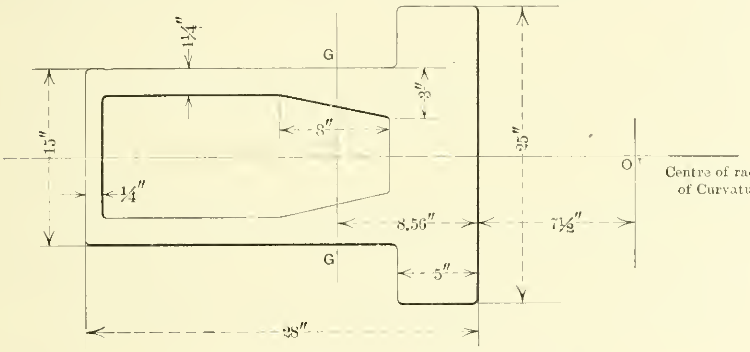

FIG. 4 DESIGN FOR A PUNCH FRAME

$A = 212 \quad I = 14{,}533 \quad k = 68.56 \quad l = 38.56 \quad \rho = 16 \quad e = 8.56$

12 It will be found much more convenient to use these empirical expressions, which give quite accurate results, than to determine the value of the functions by the more tedious graphic method.

13 In applying these empirical formulæ to punch and riveter frame sections the writer has found that the results are not accurate but that the values are better expressed as follows:

$$\gamma_2 = \frac{ke}{0.7\,\rho}$$

$$\gamma_1 = 1 + 1.1\,\gamma_2$$

For example, consider the design for a punch frame shown in Fig. 4

[1]Institute of Mechanical Engineers, Proceedings, vol. 167.

Computing the values for the functions γ_1 and γ_2 by the graphic method, $\gamma_1 = 1.4$, $\gamma_2 = 0.405$. Whereupon the intensity of stress according to the new method of analysis for a force of 90,000 lb. at the punch will be

$$f_t = \frac{W}{A}\left\{\frac{l}{\rho\gamma_2}\left(\frac{1}{\left(1-\frac{e}{\rho}\right)} - \gamma_1{}^{\frac{5}{4}}\right) + 1\right\} = 8500 \text{ lb. per sq. in.}$$

The values of γ_1 and γ_2 by the empirical formula are 1.44 and 0.4 respectively. Whereupon the intensity of stress becomes $f_t = 8500$ approximately. According to the old formula used almost exclusively in textbooks, the value of f_t is expressed by $\frac{W}{A} + \frac{Wle}{I}$, whence $f_t = 2450$.

14 The above empirical formulæ are derived from the results of computation of two sections. I am not prepared to state that it will work out in all cases and must therefore caution anyone against using these values to check the results by the graphic method. It may be clearly seen that were the punch in question designed for a limiting intensity of stress of 2450 by the old formula, there would actually be a maximum stress of 8500 lb. per sq. in., which is hardly a safe value for cast iron and particularly for a large casting.

COMMENT ON CURRENT BOOKS

Reinforced Concrete in Europe. By Albert Ladd Colby. *The Chemical Publishing Co. Easton, Pa.* 1909. Cloth, 6 by 9; x + 260 p. Price $3.

This book contains a report made to a number of "Subscribers" on current practice in reinforced concrete construction in Great Britain and on the continent, the material being collected in 1908, chiefly by personal interviews with the leading authorities in each country. Theory is but briefly dealt with, while the practical side is fully discussed, including the economy and proof of the endurance of reinforced concrete construction, the various systems in use, specifications, ingredients, mixing and construction. Considerable space is given up to the kind of steel and forms of bars in use abroad. To enable the reader to obtain further information the addresses of prominent consulting and contracting engineers of each country are given. An appendix gives the addresses of official and technical testing stations, congresses, institutions, and the like. A bibliography is also given of books, journals and periodicals dealing with the subject in each country.

Contents by chapter headings: Applications of Reinforced Concrete; Economies of Reinforced Concrete Construction; Endurance of Foreign Reinforced Concrete Construction; Foreign Systems of Reinforced Concrete Construction; Mechanical Bond and Forms of Bars; Metal Used for Reinforcement; Foreign Specifications, Recommendations and Opinions Compared; Cement Used in Reinforced Concrete; The Chief Requirements of Foreign Cement Specifications Compared; Concrete Used in Reinforced Concrete; The Chief Requirements of Foreign Concrete Specifications Compared; Reinforced Concrete; Foreign Specifications and Recommendations Compared under the Chief Specified Requirements; Lists and Description of Foreign Government and Private Testing Stations, Congresses, Technical Institutions, Associations, and Committees, who have Adopted Resolutions, Specifications, or Rules Relating Thereto; Bibliography on Reinforced Concrete, Concrete and Cement.

The Railway Locomotive. By Vaughan Pendred. *D. Van Nostrand Co. New York.* 1908. Cloth, 6 by 8; ix + 310 p.; 94 illustrations. Price $2.

The author's reason for writing this book is that he wished to deal with locomotives not "anatomically," but "physiologically." "The technical treatise deals with the locomotive almost altogether as a machine. Its parts are described, but the reasons why they assume particular shapes, and why one shape is better or worse than another are not dwelt upon, and nothing is said about the daily life of the engine." The author therefore endeavors to tell why the locomotive "is what it is." He explains the mechanical and physical phenomena on which it depends for its action, and the objects kept in view by those who design, construct and use it. He has treated the locomotive from the three standpoints of vehicle, steam generator and steam engine. The book is not intended as a "popular" work but is for engineers young in the profession. Though British practice is mainly considered, Europe and the United States receive considerable attention. The method of presentation is clear, concise and interesting.

Contents by chapter headings: Frames; Bogies; The Action of the Bogie; Center of Gravity; Wheels; Wheel and Rail; Adhesion; Propulsion; Counter-Balancing; The Boiler; The Construction of the Boiler; Stay Bolts; The Fire Box; The Design of Boilers; Combustion; Fuel; The

Front End; The Blast Pipe; Steam; Water; Priming; The Quality of Steam; Superheating; Boiler Fittings; The Injector; Cylinders and Valves; Friction; Valve Gear; Expansion; The Stephenson Link Motion; Walschaert's and Joy's Gears; Slide Valves; Compounding; Piston Valves; The Indicator; Tenders; Tank Engines; Lubrication; Brakes; The Running Shed; The Work of the Locomotive.

METALLURGY OF THE COMMON METALS (NON-FERROUS). By A. Humboldt Sexton and John S. G. Primrose. *The Scientific Publishing Co. Manchester, England.* Cloth 6 by 9; xvii + 483 pages; 185 illustrations. Price 7s. 6d.

The need felt by the authors in their work in the Glasgow and West of Scotland Technical College for a text book of the metallurgy of the common (non-ferrous) metals, has prompted the preparation of the present book. It is intended chiefly as an introduction to further study, to pursue which the student is referred to a number of books listed in an appendix.

Contents by chapter headings: Properties of Copper; Copper Minerals; The Principles of Copper Smelting; Copper Processes; Ore Dressing; Modern Methods of Copper Smelting; Matte Smelting in Blast Furnaces; Coarse Copper in Reverberatory Furnaces; Copper Refining; Wet or Leaching Processes; Electro-deposition of Copper; Properties of Tin; Working Alluvial Deposits; Tin Smelting in Reverberatory and Blast Furnaces; Refining Tin; Properties of Zinc; Dressing Zinc Ores; The English, Belgian, Silesian, and Rhenish Processes; Effect of Impurities; Properties of Lead; Preparation of Lead Ores; Smelting in Hearths; Roasting Lead Ores; Blast Furnace Smelting; Blast Furnaces for Lead Smelting; Products of Lead Smelting Fume Recovery; Wet and Electrolytic Processes; Softening and Refining Lead; Concentration of Silver in Lead; Cupellation; Electrolytic Refining of Lead; Antimony; Properties of Aluminum; Process for the Preparation of Aluminum; Properties of Nickel; Dry Methods for the Extraction of Nickel, Wet and Electrolytic Methods; Physical Constants of Metals; Thermo-Chemical Data; Factors in Calculating Blast Furnace Charges; Bibliography.

THE ELEMENTS OF MECHANICS OF MATERIALS. By C. E. Houghton. *D. Van Nostrand Co. New York.* 1909. Cloth 6 by 8; viii + 186 p.; 88 illustrations. Price $2.

The author has prepared this volume for use as an elementary text book. The extreme mathematical treatment is avoided, but where higher mathematics leads to clearness it is freely used. Review questions are given at the end of each chapter. The notation is uniform with that of Merriman's works, so that his more complete treatise may be used as a reference book.

Contents by chapter headings: Applied Mechanics; Applications; Beams; Torsion; The Elastic Curve; Long Columns; Combined Stresses; Compound Bars and Beams.

MECHANICAL ENGINEERING AND SHOP PRACTICE. By Stanley H. Moore. *Hill Publishing Co., New York,* 1908. Flexible Leather, 8vo., xv + 502 p., illustrated. Price, $4.

About one-half of this volume is devoted to a treatment of the ordinary machine shop processes and the use of machine tools, as indicated in the table of contents below. The balance of the book contains related matter of a broader character not usually included in books on shop work, but upon which the skilled mechanic should be informed in order to accomplish work intelligently. The matter referred to includes a chapter on materials, giving the strength, composition and other characteristics besides methods of hardening steel. Discussion of friction and lubrication, an outline of the principles of cutting tools, and data upon measuring and gaging work and upon screw threads, follow. The book is concluded with chapters upon power-generating machines, power transmission,

motor driving, etc. The author has included his paper delivered before this Society upon Force and Running Fits.

Contents by chapter headings: Introduction and Equipment; Materials; Friction, Lubricants and Lubrication; Cutting Tools; Measuring and Small Tools; Screw and Pin Data; Bench and Vice Work; Turning; Boring; Drilling; Grinding; Planing; Milling; Miscellaneous Machine Tools and Accessories; Shop Processes and Kinks; Mechanics; Power-Generating Machines; Elementary Electricity; Power Transmission; Motor Drives and Motor-Driven Machine Tools.

Proceedings of a Conference of Governors in the White House, Washington, D. C., May 13–15, 1908. Issued under the direction of the Committee of Governors, by W J McGee, Recording Secretary. *Washington, Govt.* Cloth, xxxvii + 451 p., illustrated.

This is a verbatim record of the six sessions of the Conference of Governors called by the President of the United States to consider the conservation of the national resources. At the conference M. L. Holman, President and Calvin W. Rice, Secretary, represented The American Society of Mechanical Engineers, by invitation of President Roosevelt, and the Secretary attended also as a specially invited guest. The discussion of the Secretary is published on Page 420, and that of H. G. Stott, Member of Council, Am. Soc.M.E., but representing the American Institute of Electrical Engineers in his capacity of President, is given on Page 404.

The *contents* include addresses and discussion on The Conservation of Ores and Related Minerals, The Waste of Our Fuel Resources, The Natural Wealth of the Land and its Conservation, Soil Wastage, Forest Conservation, Resources Related to Irrigation, Grazing on the Public Lands, Conservation of Life and Health by Improved Water Supply, Navigation Resources of American Waterways, Conservation of Natural Resources in Illinois, New York, Pennsylvania, Michigan, Wyoming, Hawaii, Washington, D. C., Florida, Iowa, Maryland, Arizona, Maine Washington, Conservation of Human Life, Our Water Resources, The Lakes-to-Gulf Waterway, Plans for Conservation, Forestry as Related to Mining Interests, The Conservation Problem, Conservation from the View-point of Recreation, Water Resources, Methods for Conservation, The Immediate Necessity for Acquiring the Appalachian Forest Reserve, Forest Conservation, Suggestions on the Conservation of Coal, Suggestions on the Conservation of Some of our Resources, Conservation in Relation to Labor, View of the Engineer, Conservation of Minerals, Railways and Conservation, The Preservation of Scenic Beauty, The Use of Some of the Natural Resources of the Country and Possible Economies of their Use, Interests of the Manufacturer, Conservation of Soils, The Twilight Zone, Necessity for Waterway Improvement, Fire Prevention, How Conservation of Mineral Resources can be Accomplished.

Tables of the Properties of Steam and Other Vapors and Temperature-Entropy Table. For Engineers and Students. By Cecil H. Peabody. *John Wiley & Sons, New York,* 1909. Eighth edition, rewritten. Cloth 8vo, v + 133 p. Price $1.

Peabody's tables of properties of saturated steam were published over twenty years ago and are in general use by engineers. In the intervening time important investigations upon the properties of steam have been made by various physicists. With these new data as a basis the original tables were recomputed and extended temperature-entropy tables were added. The edition containing the latter was issued in 1907. An edition has now been brought out in which the tables have again been recalculated to embody the refinements now rendered possible by recent important determinations relating to the properties of steam. The temperature-entropy tables give the quality, heat contents and specific volume of saturated and superheated steam for each degree of temperature fahrenheit; and for each hundredth of a unit of entropy. Such tables have become invaluable since the advent of the steam turbine in which the action of steam is assumed to

be approximately adiabatic. Calculations upon the adiabatic flow of steam and upon conditions existing in the different stages of a turbine are readily made by the use of such tables without the tedious mathematical work otherwise necessary.

Contents: Introduction; Tables; Steam, English Units, Degrees; Steam, English Units· Pounds; Steam, French and English Units; Ether; Alcohol; Chloroform; Carbon Bisulphide; Carbon Tetrachloride; Aceton; Ammonia; Sulphur Dioxid; Specific Volumes of Liquids; Volumes of Hot Water; Inches of Mercury and Pounds; Corrective Factors, Superheated Steam; Temperature-Entropy Table; Naperian Logarithms; Four-Place Logarithms.

Systems of Governing and Valve-Gears of European Gas Engines. By R. E. Mathot, Mem.Am.Soc.M.E. For sale by the author. *Brussels* (*Belgium*), 1908. Pamphlet form, 58 pages, illustrated. Price 3s.

This is a comprehensive discussion of valve gears and methods, and devices used for governing gas engines of both large and small sizes. The mechanisms illustrated are grouped under classifications relating to the principles underlying the different systems of operation; such as Governing at Constant Ratio and Volume, Variable Ratio and Constant Volume, etc. The whole comprises a systematic study of the subject.

Gear-Cutting Machinery. By Ralph E. Flanders, Assoc.Am.Soc.M.E. *John Wiley & Sons, New York*, 1909. First edition. Large 12mo, viii + 319 p., 219 illustrations. Price $3.

The author of this book contributed the paper at the last annual meeting of the Society upon Interchangeable Involute Gear Tooth Systems, which resulted in the appointment of a committee to formulate gear-tooth standards. His treatise upon gear-cutting machinery is unique in that it treats solely and with thoroughness of the different types of one form of machine tool. It explains the underlying principles of the different systems of gear cutting in use at the present time and of the mechanisms by which these systems are carried out in modern gear-cutting machines. As far as possible all of the European and English machines as well as American, are included. The method of treatment is to describe the machines and their mechanisms in the order determined, first, by the form of gear each is designed to cut; next, by the principle of action involved; next, by the method of operation employed; then by the kind of mechanism used; and finally, by the structural design of the machine. Most of the material comprising the book has appeared serially in *Machinery* of which its author is associate editor.

Contents by chapter headings: Methods of Forming the Teeth of Gears; Machines for Forming the Teeth of Spur Gears; Machines for Cutting the Teeth of Internal Gears and Racks; Machines for Cutting the Teeth of Worms and Helical Gears; Worm-Wheel Cutting Machines; Machines for Forming the Teeth of Bevel Gears.

ACCESSIONS TO THE LIBRARY

BOOKS

Applied Mechanics for Engineers. By E. L. Hancock. *New York, Macmillan Co., 1909.* Gift of publishers.

American Ceramic Society. *Transactions.* Vol. 11. *Columbus, O., 1909.* Gift.

American Society of Civil Engineers. *Transactions.* Vol. 64, 1909. *New York, 1909.* Exchange.

Association of Railway Telegraph Superintendents. *Proceedings of Annual Meeting,* June 23–25, 1909. *Milwaukee, Wis., 1909.* Gift.

Bibliography of Cotton Manufacture. By C. J. H. Woodbury. *Waltham, Mass., 1909.* Gift of author.

Brennan's Handbook. By B. A. Brennan. *New York, J. Wiley & Sons, 1908.* Gift of publishers.

Bricklaying System. By F. B. Gilbreth. *New York, M. C. Clark Pub. Co., 1909.* Gift of author.

Design of Highway Bridges and the Calculation of Stresses in Bridge Trusses. By M. S. Ketchum. *New York, Engineering News Pub. Co., 1908.* Gift of publisher.

Electric Motors. By N. G. Meade. *New York, McGraw Pub. Co., 1908.* Gift of author.

Gas Engine Theory and Design. By A. C. Mehrtens. *New York, J. Wiley & Sons, 1909.* Gift of publishers.

Gear Cutting Machinery. By R. E. Flanders. *New York, J. Wiley & Sons, 1909.* Gift of publishers.

Geological Report Upon the Gold and Copper Deposits of the Phillips River Gold Field. (Bulletin No. 35, Western Australia Geological Survey.) *Perth, 1909.* Gift.

Gyroscopic Theory of the Mechanical Part of Nature. By Jno. Bunte. *Portsmouth, Va., 1909.* Gift.

Institution of Civil Engineers of Ireland. *Transactions.* Vol. 35. *Dublin, 1909.* Exchange.

International Arbitration and Peace. The Mission of America in the Politics of the World (House of Representatives, June 14, 1909.) *Washington, Govt., 1909.* Gift.

Internal Combustion Engines. By R. C. Carpenter and H. Diederichs. Ed 2. *New York, D. Van Nostrand Co., 1909.* Gift of publishers.

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Modern Asphalt Pavement. By C. Richardson. Ed. 2. *New York, J. Wiley & Sons, 1908.* Gift of author.

Mechanical Engineering and Machine Shop Practice. By S. H. Moore. *New York, Hill Pub. Co., 1908.* Gift of author.

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National Electric Light Association. Bulletin. Vol. 3. No. 2. *New York, 1909.* Gift of C. W. Rice.

New York (State) Advisory Board of Consulting Engineers. Report to the Governor upon the Barge Canal, January 1, 1908–January 1, 1909. *Albany, N. Y., 1909.* Gift.

Patents as a Factor in Manufacturing. By E. J. Prindle. *New York, 1908.* Gift of author.

Practical Alternating Currents and Alternating Current Testing. Ed. 3. By C. F. Smith. *Manchester, Scientific Pub. Co.* Gift of publishers.

Practical Testing of Gas and Gas Meters. By C. H. Stone. *New York, J. Wiley & Sons, 1909.* Gift of publishers.

Refrigerating Machines: Compression, Absorption. By G. T. Voorhees. *London, 1909.* Gift of author.

Report on the Progress of Mining in the Districts Between Leonora and Wiluna. By A. Montgomery. *Perth, 1909.* Gift.

Report on the Waverley or Siberia District. By A. Montgomery. *Perth, 1909.* Gift.

Selden Automobile Patent Cases. Opinion of Judge Hough, filed September 15, 1909. Gift of C. W. Rice.

Simplified Methods of Calculating Reinforced Concrete Beams. By W. N. Twelvetrees. *London, Whittaker & Co., 1909.* Gift of Macmillan Co.

Steam Power Plant Engineering. By G. F. Gebhardt. *New York, J. Wiley & Sons, 1908.* Gift of publishers.

Systems of Governing and Valve-Gears of European Gas Engines. By R. E. Mathot. *Brussels, 1908.* Gift of author.

Tables of the Properties of Steam and Other Vapors, and Temperature-Entropy Table. Ed. 8. By C. H. Peabody. *New York, J. Wiley & Sons, 1909.* Gift of publishers.

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Baclé, M. L. Les Plaques de Blindages. *Paris, 1900.*

Bates, L. W. Panama Canal System and Projects. *1905.*

Chemical, Metallurgical and Mining Society of South Africa. *Proceedings.* Vol. 3. 1902–1903. *Johannesburg, 1903.*

Climatology of California. By A. G. McAide. (U. S. Weather Bureau.) *Washington, 1903.*

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Electrical Trades Directory. 1898. *London, 1898.*

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International Electrical Congress. Paris, 1900. Congrès International d'Electricité, Paris, August 18–25, 1900. *Paris, 1901.*

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Master Car Builders' Association. *Proceedings.* Vol. 37. *Chicago, 1903.*

Mines and Quarries, 1902. (U. S. Census Bureau.) *Washington, 1905.*

Paris Universal Exposition, 1878. Report of the United States Commissioners. Vol. 1–5. *Washington, 1880.* Also Report of 1889. United States Commissioners. Vol. 1–5. *Washington, 1890–1891.*

Report on Commission Named to Study Various Electro-Thermic Processes Employed in Europe for the Smelting of Iron Ores and the Manufacture of Steel. *Ottawa, Dept. of the Interior, 1905.*

Report on the Experiments Made at Sault Ste. Marie, Ont., under Government Auspices, in the Smelting of Canadian Iron Ores by the Electro-thermic Process. By E. Haanel. *Ottawa, 1907.*

Society of Naval Architects and Marine Engineers. Constitution and By-Laws and List of Members. 1897. *New York, 1897.* Transactions. 1896. *New York, 1897.*

Timber Physics. Pt. 1–2. (U. S. Agriculture Dept., Forestry Division.) *Washington, 1892, 1893.*

United States Magnetic Tables and Magnetic Charts for 1905. By L. A. Bauer. (U. S. Coast and Geodetic Survey.) *Washington, 1908.*

Wisconsin Railroad Commission. Second Annual Report. *Madison, 1908.*

TRADE CATALOGUES

Joseph Dixon Crucible Co., *Jersey City, N. J.* Catalogue of Foundry Facings applied to surface of molds. Graphite, September, 1909.

General Electric Co., *Schenectady, N. Y.* Bulletin on Panel Boards and Cabinets; Bulletin No. 4676, on the Multiple enclosed arc lamp; No. 4682, on Type F form P-3 oil break switches for spinning frames and machine tools; No. 4690, on Type MA fuse boxes; No. 4692, on G. E. 210 railway motor; Folders on White core 30 per cent Para wires and cables and Tricoat wires and cables.

Wilbur R. Kimball, *New York City.* Announcement of evening course on Aëronautics, to be given in West Side Y. M. C. A. by Mr. Kimball.

John H. Morrison, *Brooklyn, N. Y.* Announcement of "History of New York Ship Yards," by Mr. Morrison, showing the development of wooden ship building in the United States.

Reading Iron Co., *Reading, Pa.* Pamphlet on wrought-iron pipe vs. steel pipe.

Scully Steel & Iron Co., *Chicago, Ill.* Stock list of iron and steel for September, 1909.

Williamson Submarine Corporation, *Norfolk, Va.* Submarine Bulletin, August, 1909. Description of new Williamson submarine tube caisson for deep water diving.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society. and these are on file, with the names of other good men not members of the Society who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

074 Capable, energetic young man, not less than thirty years of age, to handle correspondence. Must have good business judgment. Supply all details and state salary expected. Location, Detroit, Mich.

075 Master mechanic for a beet sugar factory in Southern California employing about sixty men during repair seasons. Man must be capable of handling labor, and have had a varied experience in general machinery work. State age, past experience in full, and salary expected.

076 Mechanical draftsman, recent graduate in mechanical engineering, capable of designing pumps and heavy hoisting machinery, experienced in use of steam-engine indicator, and able to assist in testing all sorts of mechanical equipment, and making computations.

077 First-class structural draftsman, able to carry through complete designs for head-frames, tipples, coal-pockets and all sorts of buildings. Give full particulars as to experience, age and salary expected.

078 Position available for competent designer of steam pump machinery; the position would be that of assistant to the chief designer. Familiarity with hoisting machinery would be an asset. Location Middle West.

MEN AVAILABLE

311 Cornell graduate, electrical and mechanical engineer, experience as chief engineer on the design and construction of large steam-turbine power and centrifugal pumping plants, distribution systems, fire-protection systems and the electrification of industrial plants, desires to make engagement on the completion of present work, about January 1.

312 Graduate mechanical and electrical courses, W. P. I., age thirty-one, desires position in engineering or executive capacity. Experienced in engineering contracting business, and construction; has installed, repaired and operated various types of gas, steam and electrical power equipments. Competent to

prepare plans, specifications, estimates and reports; six years on the Pacific coast and previously in New England. Salary $2500. Location immaterial.

313 Experienced mechanical and electrical engineer, technical graduate, wishes responsible position with a first-class firm of consulting engineers. Is thoroughly experienced in economical operation of power plants, having served for a number of years as operating engineer in charge of a group of stations. Conversant with the most recent practice in design and operation.

314 Technical graduate, age thirty-three, active, some years' practical experience, employed and had charge of man, desires position as assistant to superintendent, testing engineer or similar position.

315 Member desires position as factory manager or mechanical engineer with concern manufacturing light or medium weight work. Long experience, best references.

316 Member, with wide commercial and technical experience in operation, design, construction and laying out of industrial plants , is open for engagement November 1.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ADAMS, Kilburn E. (Junior, 1908), Mech. Engr., Boston & Albany R.R., Rm. 372, South Sta., Boston, and for *mail*, 132 Oxford St., North Cambridge, Mass.

ALLEN, Benj. T. (1903), Ch. Engr., Harrisburg Fdy. Mch. Wks., and *for mail*, 229 S. 13th St., Harrisburg, Pa.

ALLEN, Walter C. (Junior, 1905), Genl. Mgr., Yale & Towne Mfg. Co., 9 Murray St., New York, N. Y., and 181 Greylock Pl., Stamford, Conn.

ANDERSON, Harry Warfield (Associate, 1907), 103 Candler Bldg., and *for mail*, Owens Apts., 5 E. 3d St., Atlanta, Ga.

BELL, John Everett (Associate, 1903), Mech. Engr., Babcock & Wilcox Co., 85 Liberty St., New York, N. Y., and Oradell, N. J.

BRADY, Joseph H. (1907), Ch. Engr., Bd. of Education, Room J, Pub. Library Bldg., 9th and Locust Sts., and 2115 Benton Blvd., Kansas City, Mo.

BROOME, Ernest L. (Junior, 1898), Engr., Viele, Blackwell & Buck, 49 Wall St., New York, N. Y.

CARLE, Nathaniel A. (1907), 1020 E. Demy Way, Seattle, Wash.

CHAMBERS, Norman C. (Junior, 1905), 136 W. 44th St., New York, N. Y.

CLARKE, Philip L. (Junior, 1907), White & Newcomb, Contr. Engrs., 32 Avenida de Cuicode de Mayo, Mexico City, D. F., Mex.

COON, Thurlow Emmett (Junior, 1908), 451 2d Ave., Detroit, Mich.

DEAN, ARTHUR M. (Junior, 1907), Overland Auto. Co., and *for mail*, 2716 Robinwood Ave., Toledo, O.

FRANCIS, W. H. (1884), Union League Club, Philadelphia, Pa.

HARDY, Carl E. (Junior, 1902), Asst. Supt. of Shops, Mfg. Dept., U. S. Navy Yard, Mare Is., and *for mail*, 3 N. Randolph St., Napa, Cal.

HESS, Howard D. (1903), Asst. Prof. Mch. Design, Cornell Univ., 7 South Ave., Ithaca, N. Y.

HOLL, Chas. L. (Junior, 1908), Engr., Pump Testing Dept., Allis-Chalmers Co., and *for mail*, 4612 Malden St., Chicago, Ill.

HORTON, William H. (Junior, 1904), Mech. Engr., Constr. Dept., Swift & Co., and *for mail*, 7001 Park Ave., Chicago, Ill.

HUMPHREYS, Alex. C. (1884), Manager, 1907–1910; Life Member; Pres., Stevens Inst. of Tech., Hoboken, N. J., Pres., Buffalo Gas Co., and *for mail*, Pres., Humphreys & Glasgow, 165 Broadway, New York, N. Y.

KUNZE, Edward J. (1907), Instr. Steam and Gas Engrg., Univ. of Wis., Madison, Wis.

LOCKWOOD, James Fred (1889; 1907), Mgr., Security Elev. Safety Co., 126 W. 18th St., New York, and *for mail*, 678 McDonough St., Brooklyn, N. Y.

McELROY, Jos. A. (1895), McElroy Bros., Bridgeport, Conn.

MacFARLAND, Helon Brooks (1907), Engr. of Tests, Atchison, Topeka & Santa Fe Ry. Co., Topeka, Kan.

MAHL, Fred W. (Junior, 1892), Union Pacific System and Southern Pacific Co., 135 Adams St., Chicago, Ill.

MORGAN, John R. (1901), 10227 S. Wood St., Chicago, Ill.

MURRAY, Henry H. (1899; 1905), Ch. Draftsman, Victor Talking Mch. Co., Camden, and *for mail*, 406 Lippincott Ave., Riverton, N. J.

MYERS, Curtis Clark (Junior, 1905), Shop Coördinator, Univ. of Cincinnati, Cincinnati, O.

O'KEEFE, James G. (Junior, 1907), Cadet Engr., Pub. Service Corp. of N. J., and *for mail*, 925 S. 16th St., Newark, N. J.

OLIVER, E. C. (Junior, 1902), 519 Cass Ave., Detroit, Mich.

PINNER, Seymour Wm. (Junior, 1909), Instr., Univ. of Mich., Ann Arbor, Mich.

RHOADS, George Elwood (Junior, 1906), Inspr. Tests Dept., Penn. R. R., 12th Ave. and 12th St., and *for mail*, 1320 20th Ave., Altoona, Pa.

ROBINSON, Edward (1891; 1902), Prof. of Mech. Engrg., Univ. of Vt., and *for mail*, 25 Colchester Ave., Burlington, Vt.

ROGERS, Robert W. (Junior, 1908), Erie R. R., and *for mail*, 216 Walnut St., Meadville, Pa.

ROSE, William Holladay (Junior, 1901), present address unknown.

ROWLEY, Harry Wm. (1896), Allis-Chalmers Co., 912 Evans Bldg., Washington.

SAR VANT, Wilbur Nason (Junior, 1907), 16 Verona Pl., Brooklyn, N. Y.

SERGEANT, Chas. H. (1895), 525 W. 138th St., New York, N. Y.

SLAUSON, Harold W. (Junior, 1908), Asso. Tech. Press Bureau, 25 W. 42d St., Lock Box 27, Times Sq. Sta., New York, and *for mail*, 208 Bay 22d St., Brooklyn, N. Y.

SMITH, William E. (Junior, 1908), Babcock & Wilcox Co., Barberton, O.

SPEER, Chas. Henry (Associate, 1907), Asst. Engr., Algoma Steel Co. Ltd., Sault Ste. Marie, Ontario, Canada.

STOUGHTON, Edwin R. (Associate, 1907), Baird & West, 149 Jefferson Ave., Detroit, Mich.

TAGGE, Arthur C. (1901), Engr., Internatl. Portland Cement Co., Ottawa, Ont.

THOMAS, Jay G. (Junior, 1906), Draftsman, Westinghouse Mch. Co., E. Pittsburg, and *for mail*, 500 Ellicott St., Wilkinsburg, Pa.

VAN DEINSE, A. F. (Junior, 1905), Westinghouse Elec. Co., and *for mail*, 123 San Francisco St., El Paso, Texas.

VINCENT, Jesse Gurney (Associate, 1908), Supt. of Inventions, Burroughs Adding Mch. Co., and *for mail*, 301 Addison Apts., Detroit, Mich.

VON GOEBEN, Carl (1899), Engr. and Contr., 140 Cedar St., New York, N. Y., and *for mail*, 34 Irving St., Montclair, N. J.

WATSON, Herbert L. (Junior, 1907), Sales Engr., Allis-Chalmers Co., 50 Congress St., Boston, Mass.

WIDDICOMBE, R. A. (1898; 1906), V. P. and Mgr., Dixon Steam System Co., First Natl. Bank Bldg., and *for mail*, 5552 Lakewood Ave., Chicago, Ill.

DEATHS

BLAIR, Archibald W. BRIGGS, T. Hallett HOE, Robert.

NEW MEMBERS

GOODWIN, Frank (1908), Loco. Supt., Rajputana-Malwa Ry., Ajmer, India.

McGWIRE, Charles H. (1909), U. S. P. O., Atlanta, Ga.

GAS POWER SECTION

CHANGES OF ADDRESS

ANDERSON, Harry Warfield (1909), 103 Candler Bldg., and *for mail*, Owens Apts., 5 E. 3d St., Atlanta, Ga.

OESTERREICHER, Sandor Ignatius (Affiliate, 1908), Elec. Draftsman, 823 Mt. Prospect Ave., Newark, N. J.

ROBINSON, Edward (1908), Prof. Mech. Engrg., Univ. of Vt., and *for mail*, 25 Colchester Ave., Burlington, Vt.

ROWLEY, Harry Wm. (1909), Allis-Chalmers Co., 912 Evans Bldg., Washington, D. C.

NEW MEMBERS

HAMPTON, Wm. M. (Affiliate, 1909), Supt. Gas Engs., Indiana Steel Co., and *far mail*, P. O. Box 208, Gary, Ind.

MALLON, Michael F. (Affiliate, 1909), Ch. Engr., N. Y. Div., Swift & Co., 625 Brook Ave. and 604 Tinton Ave., New York, N. Y.

QUINN, Stephen (Affiliate, 1909), Asst. Supt., Gas Eng. Dept., Indiana Steel Co., and *for mail*, P. O. Box 636, Gary, Ind.

WIGTEL, Carl (Affiliate, 1909), Ch. Engr., Watson-Stillman Co., 50 Church St., New York, N. Y.

STUDENT MEMBERS

CHANGES OF ADDRESS

BRAGAW, Richard (Student, 1909), 838 Willett St., Jamaica, N. Y.

HIGGINS, Warren S. (Student, 1909), 9 Prospect Park W., Brooklyn, N. Y.

HOLLENBERGER, Theo. J. (Student, 1909), 4433 N. Paulina St., Chicago, Ill.

WOODWARD, George W. (Student. 1909), 494 Main St., Worcester, Mass.

COMING MEETINGS

October and November

Secretaries or members of societies whose meetings are of interest to engineers are invited to send in their notices for publication in this department. Such notices should be in the editor's hands by the 18th of the month preceding the meeting.

ALABAMA LIGHT AND TRACTION ASSOCIATION
November 15, 16, annual convention, Birmingham. Secy., Lloyd Lyon, 158 Government St., Mobile.

APPALACHIAN ENGINEERING ASSOCIATION
November 5, 6, Washington, D.C. Secy., H. M. Payne, Morgantown, W. Va.

AMERICAN CIVIC ASSOCIATION
November 15–19, Cincinnati, O. Secy., Richard B. Watrous, Harrisburg, Pa.

AMERICAN GAS INSTITUTE
October 20–22, Hotel Pontchartrain, Detroit, Mich. Secy., A. B. Beadle, 25 West 39th St., N. Y.

AMERICAN RAILWAY ASSOCIATION
November 17, annual meeting, Chicago, Ill. Secy., W. F. Allen, 24 Park Pl., New York.

AMERICAN RAILWAY BRIDGE AND BUILDING ASSOCIATION
October 19–21, annual convention, Jacksonville, Fla. Secy., S. F. Patterson, Boston & Maine Ry., Concord, N. H.

AMERICAN SOCIETY OF CIVIL ENGINEERS
October 20, Paper: Characteristics of Modern Hydraulic Turbines, Chester W. Larner. Secy., Chas. W. Hunt, 220 W. 57th St., New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
October 16, Engineers' Club, St. Louis, Mo.; October 20, Chipman Hall, Boston, Mass.; November 9, 29 W. 39th St., New York. December 7–10, annual meeting, New York. Secy., C. W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS
November 9–11, annual meeting, Little Rock, Ark. Secy., A. Prescott Folwell, 239 W. 39th St., New York.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS
October 18, 19, Stratford Hotel, Chicago, Ill. Secy., W. H. Ross, 154 Nassau St., New York.

BROOKLYN ENGINEERS' CLUB
October 21, Paper: Reinforced Concrete as Applied to Piles and Cross Ties, Alex C. Chenoweth; October 28, The Reconstruction of the Hanson Place Sewer at Flatbush Ave.; November 4, Laboratory Tests of Materials for Coating Steel Pipe, by Melville C. Whipple. Secy. Joseph Strachan, 117 Remsen St., Brooklyn, N. Y.

CENTRAL RAILWAY CLUB

November 12, Hotel Iroquois, Buffalo, N. Y., 8 p.m. Paper: Application of Electricity to the Movement of Freight, G. H. Condict. Secy., H. D. Vought.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA

October 19, November 16, Prince George Hotel, Toronto, Ont. Papers: Care and Maintenance of Elevators, J. Shales; Gas Engines, their Origin and Commercial Use, G. M. Henderson. Secy., C. L. Worth, Union Sta.

EMPIRE STATE GAS AND ELECTRIC ASSOCIATION

November 17, 18, 29 W. 39th St., New York. Secy., C. H. B. Chapin.

ENGINEERS' CLUB OF TORONTO

October 21, 8 p.m., 96 King St. W. Paper: The Air as a Medium of Transportation, J. F. d'Almeida. Secy., R. B. Wolsey, 25 Lowther Ave.

MODERN SCIENCE CLUB

October 19, 125 S. Elliott Pl., Brooklyn, N. Y. Paper: Air Compressors, S. B. Redfield. October 26. Paper, Power, F. L. Johnson. Secy., J. A. Donnelly.

NATIONAL MUNICIPAL LEAGUE

November 15–18, Cincinnati, O. Secy., C. R. Woodruff, 121 S. Broad St., Philadelphia, Pa.

NEW YORK RAILROAD CLUB

November 19, annual meeting, 29 W. 39th St. Secy., H. D. Vought, 95 Liberty St.

OHIO SOCIETY MECHANICAL, ELECTRICAL & STEAM ENGINEERS

November 19, 20, main annual meeting, Lima, O. Secy., David Gaehr, Schofield Bldg., Cleveland.

RAILWAY CLUB OF PITTSBURG

October 22, annual meeting, Monongahela House. Secy., J. D. McIlwain, care P. & L. E. R. R.

RICHMOND RAILROAD CLUB

November 8, annual meeting. Secy., F. O. Robinson.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

November 18–19, annual meeting, 29 W. 39th St., New York. Secy., W. H. Baxter.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB

November 18, annual meeting, Candler Bldg., Atlanta, Ga. Papers on Oil Lamps, Front-End Arrangements, Draft-Rigging. Secy., A. J. Merrill, 218 Prudential Bldg.

WESTERN ASSOCIATION OF ELECTRICAL INSPECTORS

October 26–28, annual meeting, Detroit, Mich.

WESTERN SOCIETY OF ENGINEERS

October 20, November 3, 20, 1735 Monadnock Blk., Chicago, Ill. Papers: Hydraulic Mining of Auriferous Gravels, J. W. Phillips; Loss of Heat through Furnace Walls, W. T. Ray, Henry Kresinger; The Panama Railroad, Ralph Budd.

MEETINGS TO BE HELD IN THE ENGINEERING BUILDING

Date	Society	Secretary	Time
October			
15	New York Railroad Club	H. D. Vought	8.15
19	New York Telephone Society	T. H. Lawrence	8.00
27	Municipal Engineers of City of New York	C. D. Pollock	8.15
November			
3	Wireless Institute	S. L. Williams	7.30
4	Blue Room Engineering Society	W. D. Sprague	8.00
5	Explorers' Club	H. C. Walsh	8.30
6	Amer. Soc. Hungarian Engrs. and Archts	Z. deNemeth	8.30
9	The American Society of Mech. Engrs	Calvin W Rice	8.00
11	Illuminating Engineering Society	P. S. Millar	8.00
12	American Institute of Electrical Engrs	R. W. Pope	8.00
16	New York Telephone Society	T. H. Lawrence	8.00
17–18	Empire State Gas and Electric Asso	C. H. B. Chapin	All day
18–19	Naval Architects and Marine Engrs	W. H. Baxter	All day
19	New York Railroad Club	H. D. Vought	8.15
24	Municipal Engineers of City of New York	C. D. Pollock	8.15

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G. T. Voorhees
A. P. Trautwein
Philip De C. Ball
E. F. Miller

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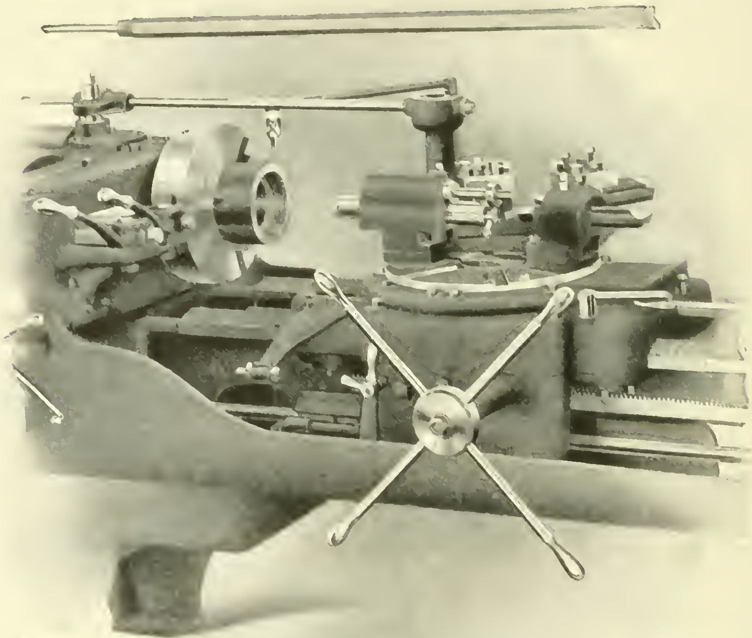

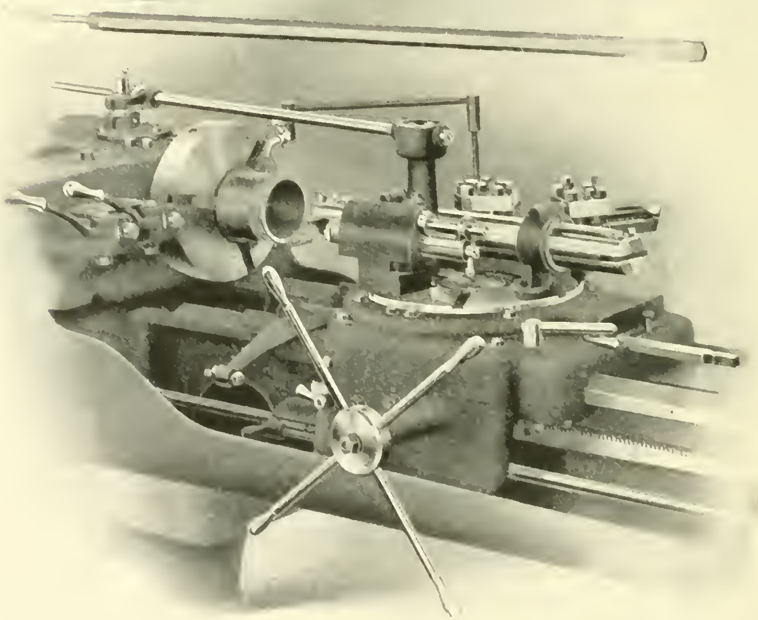

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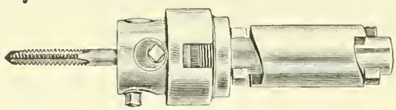

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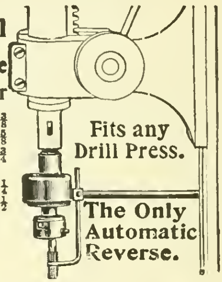

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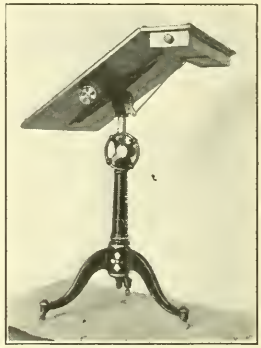

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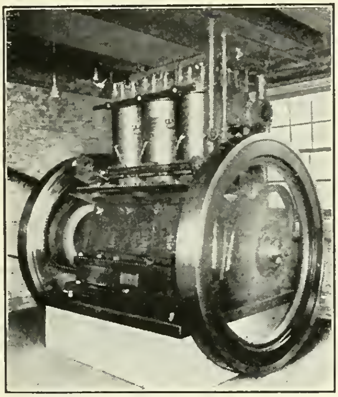

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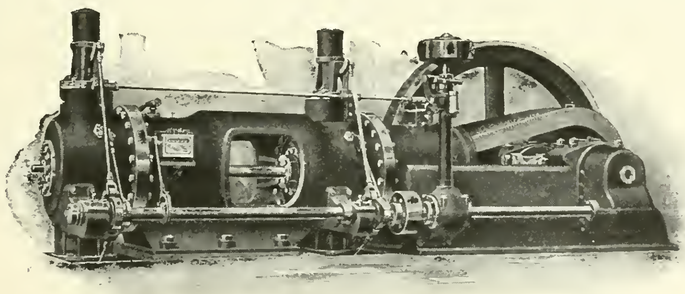

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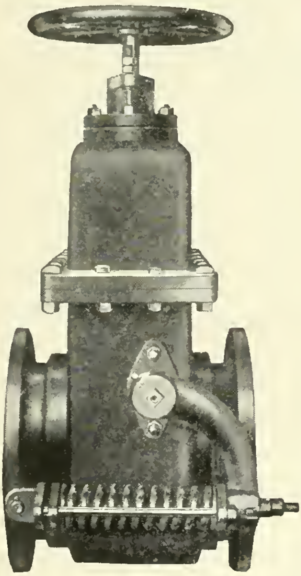

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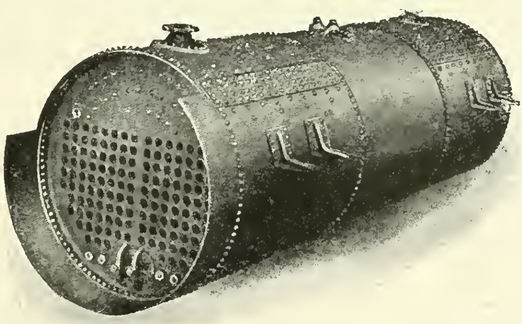

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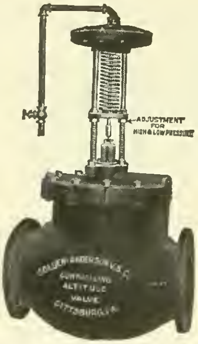

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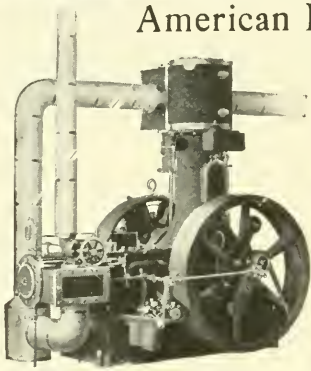

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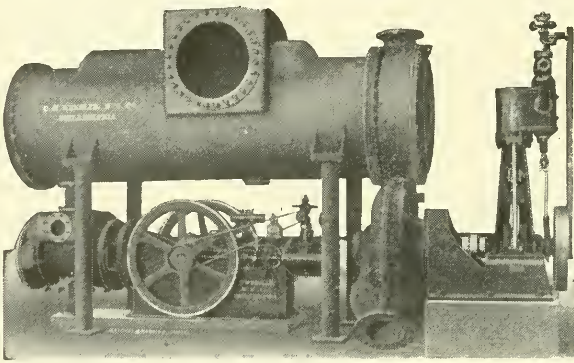

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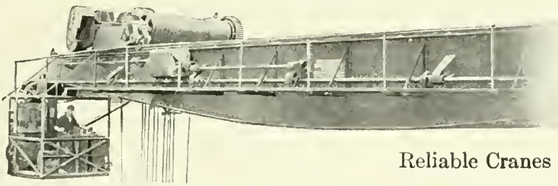

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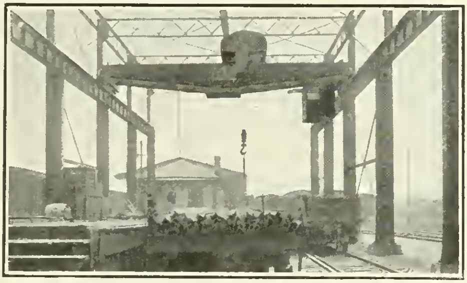

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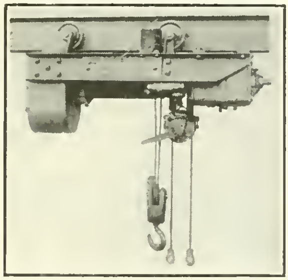

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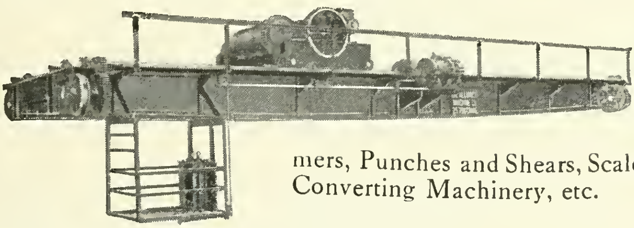

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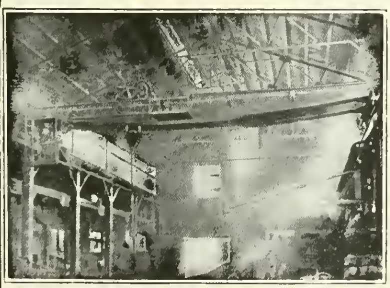

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No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No. 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

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THE

JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

NOVEMBER 1909

MEETINGS OF THE SOCIETY: NEW YORK, NOVEMBER 9; ST. LOUIS, NOVEMBER 13; BOSTON, NOVEMBER 17; ANNUAL MEETING, NEW YORK, DECEMBER 7-10

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The Journal is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.
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THE JOURNAL

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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 NOVEMBER 1909 NUMBER 10

THE next New York monthly meeting will be held on Tuesday evening, November 9. Two papers will be presented, one by Prof. Gaetano Lanza of the Massachusetts Institute of Technology on Reinforced Concrete Beams, the other by Prof. Walter Rautenstrauch of Columbia University, on The Design of Curved Machine Members under Eccentric Load. The paper by Professor Lanza will be illustrated by lantern slides showing methods of testing full-sized beams. The paper by Professor Rautenstrauch will be discussed by authorities on machine design.

On Saturday evening, November 13, The American Society of Mechanical Engineers and the Engineers' Club of St. Louis will meet together in the rooms of the Engineers' Club, 3817 Olive Street, St. Louis. A paper will be presented upon A Modern Boiler Shop, by E. R. Fish, Secretary of the Heine Safety Boiler Co., St. Louis.

In Boston, a meeting will be held Wednesday evening, November 17, with a topical discussion on Low-Pressure Steam Turbines. This discussion will be participated in by W. L. R. Emmet, General Electric Co., Schenectady, N. Y.; H. G. Stott, Interborough Rapid Transit Co., New York; Richard H. Rice, General Electric Co., West Lynn, Mass.; Prof. Edward F. Miller, Massachusetts Institute of Technology, and others.

ANNUAL MEETING

The annual meeting of The American Society of Mechanical Engineers will be held in the Engineering Societies' Building, New York,

December 7 to 10. The arrangements for the meeting are now being completed by the Meetings Committee and a fuller announcement will be made in a later issue of The Journal.

SOCIAL FEATURES OF THE ANNUAL MEETING

A meeting of the members resident in and about the city of New York was held in the rooms of the Society on the evening of Tuesday, October 19, to discuss ways and means for the reception of the members at the time of the annual meeting in return for courtesies when attending the conventions in other cities.

The meeting was called to order by the President, who was chosen chairman. After explaining the object of the meeting and the rule passed by the Council last winter, placing in the hands of the members the full charge and responsibility for the social features, the President called for nominations for chairman of the local committee, and William D. Hoxie was unanimously elected with authority to appoint a local reception committee. An informal discussion followed in regard to the conduct of the annual meeting and many helpful suggestions were obtained.

RAILROAD TRANSPORTATION NOTICE

For members and guests attending the Annual Meeting in New York, December 7-10, 1909, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 3 and 9 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival, present your certificate to S. Edgar Whitaker at headquarters, with 25 cents for validation. A certificate cannot be validated after December 10.

d An agent of the Trunk Line Association will validate certificates December 8, 9 and 10. No refund will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for certificate, and to turn it in at headquarters. Even though you may not use it this will help others to secure the reduced rate.

f If certificate is validated, a return ticket to destination can be purchased, up to December 14, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlotteville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

New England Passenger Association, except via Bangor and Aroostook R. R., Rutland R. R., N. Y. O. & W. R. R., Eastern Steamship Co. and Metropolitan Steamship Co.

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri; north of a line through Kansas, Jefferson City and St. Louis, Illinois; north of a line from Chicago through Peoria to Keokuk.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

MEETING IN GREAT BRITAIN

JOINT MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND THE INSTITUTION OF MECHANICAL ENGINEERS

The Society has received an invitation from The Institution of Mechanical Engineers of Great Britain to hold a joint meeting with them in the Summer of 1910. The letter of invitation and President Smith's reply follow:

THE INSTITUTION OF MECHANICAL ENGINEERS
Storey's Gate, St. James Park, Westminster, S. W.
17th September, 1909.

Dear Mr. President:

At a Meeting of the Council of this Institution held today, the following Resolution was unanimously passed:

"That a very hearty invitation be sent to The American Society of Mechanical Engineers to participate in a Joint Meeting in England with the Institution of Mechanical Engineers, and that the Meeting be held in the Summer of 1910, if possible during the last week in July."

I need scarcely say how warmly the subject was supported by those present, especially as the Council had learnt from the Committee appointed to confer with Mr. H. deB. Parsons, the special representative of your Society, the cordiality with which the idea had been taken up by your Members.

We hope that we may be favored with the presence of yourself, your Council, and many of your Members at the proposed Meeting.

With all good wishes, we are,

Yours very truly,
JOHN A. F. ASPINALL
President
EDGAR WORTHINGTON
Secretary

The President
The American Society of Mechanical Engineers
29 West 39th Street, New York, U. S. A.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
29 West 39th Street, New York, U. S. A.

Dear Mr. President:

The Council of The American Society of Mechanical Engineers has considered the very cordial invitation of The Institution of Mechanical Engineers, to hold a joint meeting in England in the summer of 1910, conveyed by your letter of September 17.

The Council was unanimous in the acceptance of the invitation and bids me convey to you its action as follows:

"Resolved,—That The American Society of Mechanical Engineers accept the very cordial invitation of The Institution of Mechanical Engineers, to hold a joint meeting in England in the Summer of 1910. The Council feels that the interests of Engineering throughout the World will assuredly be advanced by the giving and the acceptance of this invitation;—an evidence of an increasing coöperation among the various societies representing the Profession of Engineering."

In conveying this resolution of the Council permit us to inform you of the universal cordiality with which the invitation has been received both by the Council and by the Members of the Society. It is the expectation that a representative delegation of the Society will be present at the meeting.

Please accept our expressions of sincere good will.

JESSE M. SMITH
President
CALVIN W. RICE
Secretary

To The President
The Institution of Mechanical Engineers
London, England

Fuller details of the meeting will be sent out shortly to the entire membership, with reply cards, to enable the Executive Committee who have the matter in hand to estimate the number of members who may possibly wish to participate in this extraordinary opportunity for professional and social meetings with a sister society.

The meetings will begin July 26, and conclude on July 29.

Interesting special exhibitions are to take place in Brussels, Düsseldorf and other cities, and the Passion Play will be produced next year at Oberammergau, for the first time in ten years.

A considerable number of the representative members of the Society and ladies have already signified their intention of going, so that the undertaking is now an assured success.

OCTOBER MEETINGS OF THE SOCIETY

NEW YORK, OCTOBER 12

At the meeting of the Society held October 12 in the lecture room on the fifth floor of the Engineering Societies' Building, Prof. R. C. Carpenter presented his paper on The High-Pressure Fire-Service Pumps of Manhattan Borough, City of New York. Pres. Jesse M. Smith presided. The attendance was 192.

Secretary Calvin W. Rice announced the meetings of the Society in St. Louis on October 16 and in Boston on October 20, and the invitation of the Institution of Mechanical Engineers to hold a joint session with them from July 26 to July 29, 1910. The President then introduced the following Japanese commissioners visiting the United States to study various industries: Dr. Ryota Hara, doctor of engineering and chief engineer of Yokohama; Rinnosuke Hara, of the Japanese Architectural Society; Junkichi Tanabe, of Tokyo, of the Institute of Japanese Architects; and Narazo Takatsuji, director of a large spinning factory. A telegram of regret was received from Kojiro Matsukata, the leading shipbuilder of Japan.

So large a number of the members identified with the centrifugal pump industry had manifested a desire to discuss the paper that the pump feature of the paper was emphasized. Those participating in the discussion are considered authorities in the design and operation of centrifugal pumps and many interesting facts were brought out in regard to the efficiency of the New York fire pumps and of centrifugal pumps in general. Representatives from the department of water supply, gas and electricity also contributed to the interest of the discussion, speaking from the standpoint of reliability and of distribution.

Those taking part in the discussion were: Prof. Geo. F. Sever, William M. White, Geo. L. Fowler, John H. Norris, J. R. Bibbins, J. J. Brown, Geo. A. Orrok, Frederick Ray, H. Y. Haden, Thos. J. Gannon, Henry B. Machen, Richard H. Rice, Chas. A. Hague. Written discussions were submitted by: A. C. Paulsmeier, Prof. W. B. Gregory, Wm. O. Webber and Chas. B. Rearick.

At the close of the discussion Mr. White showed a number of lantern slides giving efficiency curves of various pumps designed by the I. P. Morris Co., Philadelphia, Pa.

Mr. Fowler, with the aid of lantern slides, described the work of centrifugal pumps in dredging, and exhibited the following as evidence of the great suction capacity of these pumps:

A piece of shaft weighing 70 lb. raised and passed by a 15-in. dredging pump; improvement of New York Harbor, Steamer Reliance.

A piece of tree root raised and passed by a 12-in. pump from 14 ft. of water at Miami, Fla.; Florida East Coast Railway Company improvements.

A piece of pig iron measuring $11\frac{1}{2}$ in. by $4\frac{3}{4}$ in. by $3\frac{1}{4}$ in. and weighing 35 lb., raised and passed by a 8-in. special cataract wrecking pump from 15 ft. of water from the wreck of a canal boat sunk at Puas Dock, Yonkers, N. Y., by the Baxter Wrecking Company, New York.

MEETING, AM. SOC. M. E., ENGINEERS' CLUB OF ST. LOUIS, ST. LOUIS, OCTOBER 16

The first meeting of the two societies was held at the rooms of the Engineers' Club of St. Louis at 8.15, Saturday evening, October 16, under the direction of William H. Bryan, Chairman, M. L. Holman and E. L. Ohle, Secretary, of the local joint committee.

A letter from President Jesse M. Smith was presented, indicating the sentiment of the Society towards local meetings. This was responded to briefly by President E. E. Wall, of the Engineers' Club of St. Louis, who reciprocated the sentiments of President Smith, and emphasized his belief in the advantages of coöperation.

Prof. R. C. Carpenter of Cornell then presented in abstract his paper on The High-Pressure Fire-Service Pumps of Manhattan Borough, City of New York, accompanying it by running comments and comparisons.

He was followed by Horace S. Baker, Assistant Engineer of the City of Chicago, who presented the results of recent study with a view of adopting high-pressure service. His talk was illustrated. E. E. Wall, assistant water commissioner, City of St. Louis, outlined the plan proposed for high-pressure fire service in St. Louis. He was followed by H. C. Henley, chief inspector, St.Louis fire prevention bureau, and vice-president of the National Fire Protection Association, expressing views of the fire insurance authorities, entirely favorable to the installation of such systems when properly designed and operated. Chas E. Swingley, chief of the St. Louis fire department, on invitation, responded briefly to the effect that such systems were of

undoubted advantage in the congested districts of large cities, and expressed the hope that something might be done soon along this line in St. Louis. There was further brief discussion by Edw. Flad, Prof. W. H. Hibbard, and H. C. Toensfeldt.

Luncheon was served by the Engineers' Club of St. Louis. The attendance was 100.

MEETING AM.SOC.M.E., BOSTON SOCIETY OF CIVIL ENGINEERS, BOSTON, OCTOBER 20

On Wednesday evening, October 20, a joint meeting of the Society with the Boston Society of Civil Engineers was held in the latter society's rooms, Tremont Temple, Boston, Mass.

Chas. T. Main, vice-president of the Boston Society of Civil Engineers, presided. Following the routine business of the Society of Civil Engineers, Mr. Main read a letter from Jesse M. Smith, President of The American Society of Mechanical Engineers, regretting that he could not be present at the meeting, and wishing the Boston members success for their coming meetings. An announcement was also read of the next meeting in Boston of The American Society of Mechanical Engineers, to be held in Room 6 of the Lowell Building, Massachusetts Institute of Technology, November 17; full announcement appears elsewhere in The Journal.

A paper by Gaetano Lanza, professor, and Lawrence F. Smith, instructor at the Massachusetts Institute of Technology, on Stresses in Reinforced Concrete Beams, was read by the former. Following the presentation of the paper, a discussion by J. R. Worcester was read in his absence by Mr. Tinkham, Secretary of the Society of Civil Engineers. Sanford Thompson, Fred S. Hines, Henry Bryant and Geo. F. Swain contributed oral discussions.

The total attendance at the meeting was 180, of whom 60 were members of the Society of Civil Engineers, 50 were members of The American Society of Mechanical Engineers and 70 were guests.

MEETING OF THE COUNCIL

A meeting of the Council was held on October 12, 1909, in the rooms of the Society, Jesse M. Smith, President, presiding. There were present: Messrs. Breckenridge, Carpenter, Gantt, Sando, Humpphries, Hunt, Miller, Moultrop, Waitt, Whyte and the Secretary. A letter of regret was received from G. M. Basford.

The deaths of the following were reported; Archibald W. Blair, T. Hallett Briggs, Robert Hoe, R. B. Lincoln, George W. West.

The following resignations were accepted: R. T. Close, Samuel G. Colt, H. Harcourt Dixon, Wm. L. Draper, Walter Flint, T. A. Hilles, Edmund Kent, W. P. Norton, F. J. Plummer, Edward L. Ross, Lucien N. Sullivan.

The Council confirmed the appointment of Honorary Vice-Presidents as follows: National Conservation Congress, Seattle, Wash., R. M. Dyer, M. K. Rodgers, W. F. Zimmermann; American Mining Congress, Goldfield, Nev., Dr. J. A. Holmes.

Japanese Honorary Commercial Commission. The President reported that he and the Secretary had called upon the Japanese Honorary Commercial Commission and extended to them the courtesies of the Library and the rooms of the Society and that he had invited the engineer members of the Commission to attend the meeting of the Society that evening.

EXECUTIVE COMMITTEE

Professional records, September 1909. The Council approved of the applications for membership as shown in the professional service sheet of September 1909 and under By-Law 2 gave specific approval of the following applicants who do not live in the United States: Arthur N. Blum, Luis Alberto Carbo, Louis Edward Polhemus, Henry Terry Purdy, Mark Robinson.

COMMITTEE ON CONSTITUTION AND BY-LAWS

The following amendments recommended by the Committee on Constitution and By-Laws were approved:

Trustee of the United Engineering Society:

B– The Council shall, previous to January 1 of each year, elect a trustee to serve for a term of three years on the Board of Trustees of the United Engineering Society. No trustee shall be eligible for more than two years consecutively.

Expenses of Section Meetings:

R24 Expenditures for the purposes of a section chargeable to the Society shall be authorized by the Secretary of the Society before they are incurred, and must be provided for in the estimate and budget of the Committee on Meetings. No liability otherwise incurred shall be binding on the Society. Any expenditure not so provided shall be met by the section itself.

The Journal:

B– The Council shall institute a monthly publication to be called "The Journal," which shall be under the management of the Secretary, who shall act under the general supervision of the Publication Committee, subject to approval by the Council as to the policy thereof and the expenditures therefor. The annual subscription price of The Journal to each member is five dollars, and is included in the annual dues of such member.

Election of members:

B6 The Secretary shall mail at least thirty days in advance of each annual or semi-annual meeting to each member entitled to vote, a ballot stating the names and the respective grades of the candidates for membership in the Society which have been approved by the Council, and the time of the closure of the voting. The voter shall prepare his ballot by crossing out the name of any candidate rejected by him, and shall enclose said ballot in an envelope and seal the same; he shall then enclose said envelope in a second envelope marked "Ballot for Members," and seal the same, and he shall then write his own name thereon for identification. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the tellers of election. The Secretary shall certify to the competency and the signature of all voters. A ballot without the autographic endorsement of the voter written on the outer envelope is defective, and shall be rejected by the tellers of election.

B7 The voting for the election of members shall close at twelve o'clock noon five days in advance of the day on which the annual or semi-annual meeting begins. The tellers of election shall first open and destroy the outer envelopes, and shall then open the inner envelopes and canvas the ballot, and certify the result to the President or presiding officer of the Society, at the first session of the current meeting of the Society. The tellers shall not receive any ballot after the stated time for the closure of the voting.

Election of Officers:

B12 The Secretary shall mail on or before the last Thursday in October of each year to each member entitled to vote, a ballot stating the names of the candidates for the several offices falling vacant, and the time of the closure of the voting. The voter shall prepare his ballot by crossing out the name of any candidate or candidates rejected by him, and may write in the name of any eligible member of the Society. The voter shall enclose said ballot in an envelope and seal the same. He shall then enclose the sealed envelope in a second envelope marked "Ballot for Officers," seal the same, and shall then write his name thereon for identification. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the tellers of election. The Secretary shall certify to the competency and signature of all voters. A ballot without autographic endorsement of the voter written on the outside envelope is defective, and shall be rejected by the tellers of election. A ballot which contains more names than there are offices to be filled is thereby defective, and shall be rejected by the tellers.

B13 The voting for the election of officers shall close at twelve o'clock noon on the Thursday preceding the first Tuesday of December in each year. The

tellers shall not receive any ballot after the stated time for the closure of the voting. The tellers of election shall first open and destroy the outer envelopes and shall then open the inner ones, canvass the ballots and certify the result to the President, at the first session of the current meeting of the Society. The presiding officer shall then announce the candidates having the greatest number of votes for their respective offices, and declare them elected for the ensuing year.

B34 The President shall on or before the last Thursday in October of each year, appoint three tellers of election of officers, whose duty shall be to canvass the votes cast, and certify the same to the President at the first session of the annual meeting. Their term of office shall terminate when their report of the canvass has been presented and accepted.

Library of the Society:

R16 The Library of the Society shall be conducted as a free public reference library of engineering and the allied arts and sciences. It shall be open on all week days between the hours of 9 a.m. and 9 p.m., except New Year's, Independence, Thanksgiving and Christmas days. The rooms of the Society shall be open for the use and the convenience of members during the usual business hours.

Library Committee:

B27 The Library Committee shall consist of five persons who shall be Members, Associates or Juniors. The term of office of one member of the Committee shall expire at the end of each annual meeting. It shall be the duty of the Library Committee to coöperate with similar committees of the American Institute of Electrical Engineers and the American Institute of Mining Engineers, in the care and development of a library. At the end of each fiscal year the committee shall deliver to the Secretary a detailed report of its work.

House Committee:

B28 The House Committee shall consist of five persons who shall be Members, Associates or Juniors. The term of office of one member of the Committee shall expire at the end of each annual meeting. It shall be the duty of the House Committee to have the care, management and maintenance of the Rooms of the Society and furnishings, the historical relics, the paintings, and objects of art, and to recommend to the Council suitable regulations for their care and use. At the end of each fiscal year, the committee shall deliver to the Secretary a detailed report of its work.

Author's Copies:

The Secretary may furnish to the author twenty copies of his paper without charge. The Secretary may furnish to the technical press such papers as they may wish to publish which have been published in The Journal.

Fees:

B18 The initiation fees and annual dues of the first year shall be due and payable on notice of election to membership, and upon that payment the member

shall be entitled to the Transactions for the year. Thereafter the annual dues shall be due and payable on the first day of October in each year for the ensuing twelve months.

B19 A member in arrears for dues for one year shall not be entitled to vote. Should the right to vote be questioned, the books of the Society shall be conclusive evidence. The resignation of a Member indebted to the Society shall not be accepted.

Voted: To approve the following directions to the Secretary:

That the Secretary be instructed to print on each ballot the date of closure of voting, and a reference to the By-Law that the ballot will not be canvassed if not received at that time, and to include a statement urging every member to cast a vote.

That the Secretary shall mail on or before the last Thursday of October of each year to each member entitled to vote, a ballot stating the names of the several candidates for offices proposed for election by the Nominating Committee or committees, and specifying the number of officers to be elected and the time of the closure of the voting.

Revision of the Constitution

Voted: That when final action on the Constitution and By-Laws is taken, the necessary re-arrangement, re-numbering, etc., be made.

Voted: To request the Committee on Constitution and By-Laws to go over the entire Constitution and By-Laws and also the amendments considered above and in such places where there is a distinction made between President and Presiding Officers, the Committee rephrase the language to make it consistent and report to the Council at the next meeting.

FINANCE COMMITTEE

Voted: To approve the following motions from the Minutes of the Finance Committee, October 1909:

"*Voted:* The Finance Committee recommend to the Council that transfers be made of unexpended appropriations and also additional appropriations according to attached list, to meet the excess in expenditures of the various committees for the fiscal year ending September 30, 1909, these appropriations all being within the current income for the year, leaving a total unexpended and unappropriated income of $1,639.18.

"*Voted:* That the excess of current income ($1,639.18) over current expense for the fiscal year 1908–1909 be applied to the reduction of the account, Advances Preliminary to Advertising."

Voted: To cancel the unexpended appropriation of the Increase of Membership Committee, $368.48, and the Library Committee, $464.16, by crediting the same to the appropriations for the other committees.

Voted: To approve the additional appropriations to the amount of $10,734,99, the same being within the income of the Society, for the work of the year just closed, as follows:

Finance Committee	$2012.27	
Membership Committee	392.36	
House Committee	390.76	
Meetings Committee	759.73	
Publication Committee	4099.68	
Research Committee	0.58	
Sales—Expenditures	3901.00	
Committee on Power Tests	11.25	
		$11,567.63
Available Balances:		
Increase of Membership Committee	368.48	
Library Committee	464.16	832.64
Appropriation required		$10,734.99
Total unappropriated income		12,374.17
Excess of income over expenditures		1,639.18

Budget for 1910. The budget for the fiscal year 1909–1910 as recommended by the Finance Committee was approved by the Council as follows:

Current Income estimate 1909–10		Current Expense	
Dues Current	$50,000	Finance Committee	$26,000
Dues arrears	2,000	Membership Committee	2,400
Reserve fund, 10 per cent	3,400	Increase Committee	500
Sales gross receipts	5,000	House Committee	1,150
Interest	2,200	Library Committee	2,880
Advertising	21,000	Meetings Committee	8,050
		Publication Committee	34,900
		Research Committee	500
	$83,600	Executive Committee	600
		Committee on Power Tests	500
		Sales Expenditures	3,000
			$80,480
Excess of income over expenses			3,120
			$83,600

Voted: To adopt the recommendation of the Finance Committee as follows: That Finance Committee be requested to investigate the financial situation of the Society and make a report to the Council.

MEMBERSHIP COMMITTEE

Voted: To approve under C16, upon the request of Herbert J. White and the recommendation of the Membership Committee, the placing of his name again on the ballot for membership, for the annual meeting 1909.

Voted: To approve the request of July 28, 1909, of F. W. Jackson, as approved by the Membership Committee, for reinstatement in the Society, to date from October 1, 1909.

JOHN STEVENS' PART IN THE DEVELOPMENT OF STEAM NAVIGATION

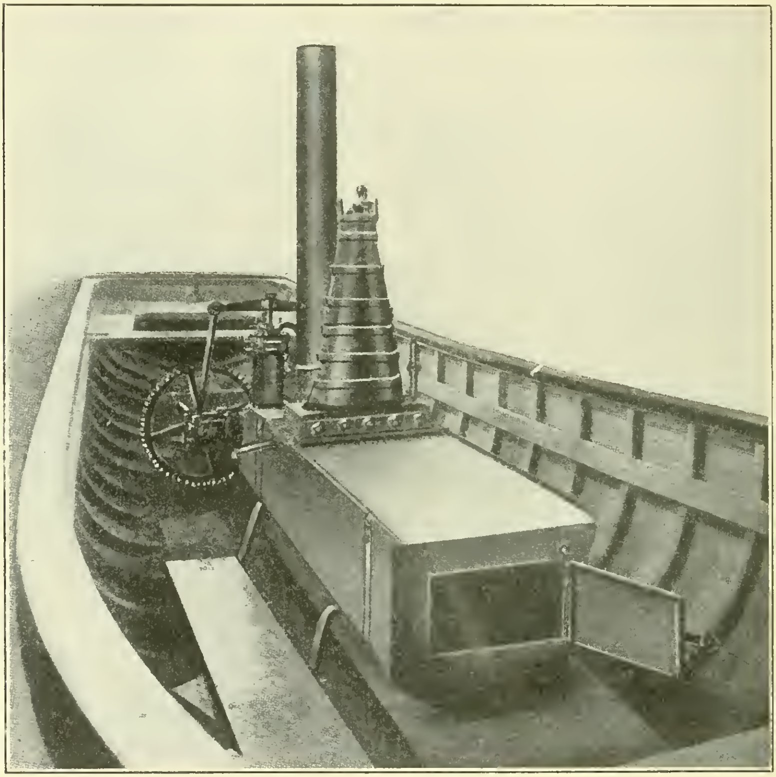
The City of Hoboken, N. J., on the evening of October 7, celebrated its connection with the progress in steam navigation through the work of Col. John Stevens and his sons, Robert L. and Edwin A. Stevens. The local celebration committee had arranged to exhibit on floats the models of the Phœnix, built by John Stevens, and of John Fitch's boat, loaned to The American Society of Mechanical Engineers by the Smithsonian Institution. John Stevens and his sons played such an important part in the development of steam navigation and steam railroads that a brief history of their work is given here.

John Stevens was born in New York in 1749. Graduating from Kings College, now Columbia University, in 1768, he studied law and was admitted to the bar. He served with distinction in the Revolution and was at one time treasurer of New York state. His winter home was on Broadway, New York, and his summer residence at Hoboken, N. J., then an island. Having ample means, he was not hampered in his steamboat experiments.

One writer states that Stevens was first attracted to steamboat development when he saw Fitch's boat on the Collect Pond in New York City in 1796. Another writer places the time in 1787, when Stevens saw Fitch's boat on the Delaware near Burlington, N. J.

That he also followed Rumsey's experiments with interest is shown by a letter to Rumsey in 1788, in which he writes: "Your invention of generating steam by means of a worm is certainly of the utmost importance, but more particularly when applied to the purposes of navigation." Stevens then describes a boiler to be formed of a helix of copper pipe, suspended in a cylindrical stove, the turns of the helix to lie close so as to prevent air and smoke passing between them. From the top of the "worm" a flue extended 12 or 18 in. above the stove. Fuel was placed on a grate in the upper part of the stove, around the flue. The path of the air was downward through the fire, the gases passing around the worm to the bottom of the stove and up the inside and through the flue.

On January 9, 1789, Stevens applied to the New York legislature for "an exclusive privilege to build steamboats on a plan lately by him invented." In his petition he said that "to the best of his knowledge and Belief, his Scheme is altogether new, or at least does not interfere with the Inventions of either of the Gentlemen (probably Fitch and Rumsey) who have applied . . . . for an exclusive



Twin-Screw Engine and Boiler Built by Col. John Stevens in 1804. View Taken from near the Bow Looking Toward the Stern

Right of navigating by means of Steam." He prays "That in case his machine should appear to be a new and useful Invention that the Honorable the Legislature would be pleased to grant to him an exclusive privilege and Right of using the same for the purpose of navigation throughout the State of New York for such terms of Years as shall seem meet."

The petition was read and referred to the committee considering Rumsey's petition for a monopoly which had been filed previously. Rumsey's petition was granted, doubtless solely on the fact of priority of presentation.

In 1790 John Stevens petitioned Congress for the formulation of a patent law, and it was on this petition, says Dr. J. E. Watkins, that the law of 1790, the foundation of the American patent system, was framed.

In 1792 Stevens took out patents for propelling vessels by steam pumps modified from the original steam pumps of Savary. In 1798 an experimental boat of 30 tons was tried on the Passaic River, in New Jersey, "a horizontal centrifugal wheel drawing water from the bottom of the boat and discharging it at the stern." In these experiments Stevens was associated with Nicholas J. Roosevelt, Isambard Brunel, an exiled French royalist, and Chancellor Robert R. Livingston, Stevens' brother-in-law. It is said that in the same year, a boat was successfully tried on the Hudson, but details are not given.

Stevens' experiments in screw propulsion began in 1801, continuing until some time in 1806. Stevens believed himself to be the inventor of screw propulsion, but, as one of his descendants, Francis B. Stevens, writes, he was mistaken. It was proposed by the mathematician Bernouli in 1752, and was described by Bushnell in 1787 in a letter to Thomas Jefferson, describing a submarine boat to which was attached a screw propeller worked by hand.

The engines used in 1802, 1803 and 1804 were all non-condensing, the boilers being multitubular and generating steam at high pressure. The propeller was of the short 4-blade type now in common use. The engine and the results obtained with it are described in a letter from Stevens to the Medical and Philosophical Journal of New York, January 1812:

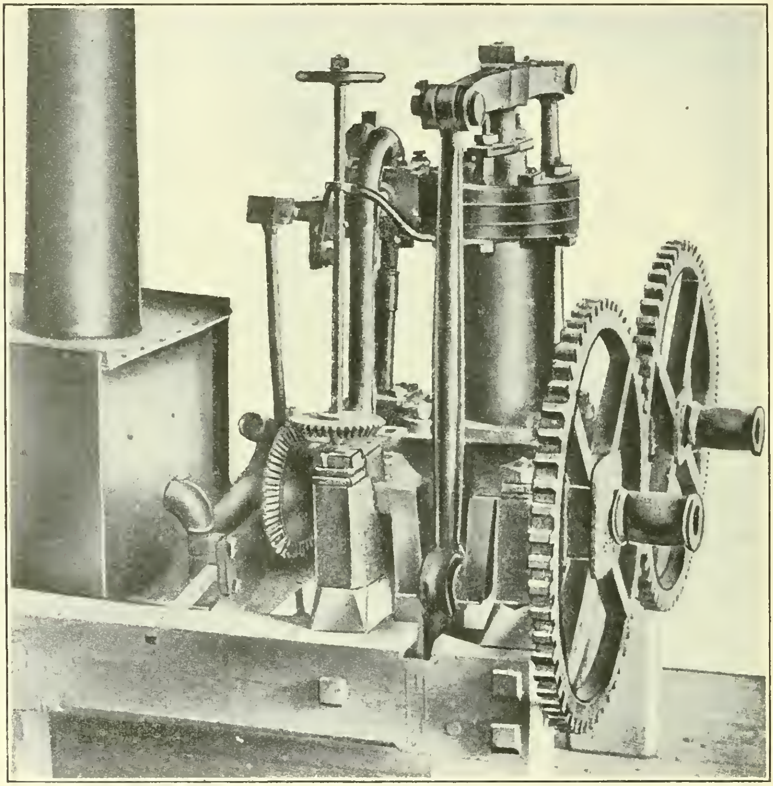
"A cylinder of brass, about 8 in. in diameter, and 4 in. long, was placed horizontally on the bottom of the boat; and by the alternate pressure of the steam on two sliding wings, an axis passing through its center was made to revolve. On one end of this axis, which passed through the stern of the boat, wings, like those on the arms of a windmill, were fixed, adjusted to the most advantageous angle for operating on the water.

"This constituted the whole of the machinery. Working with the elasticity of the steam merely, no condenser, no air pump was necessary; and as there were no valves, no apparatus was required for opening and shutting them. This simple little steam engine was, in the summer of 1802, placed on board a flat-bottomed boat I had built for the purpose. This boat was 25 ft. long, and about 5 or 6 ft. wide. She was occasionally kept going until the cold weather stopped us. When

the engine was in the best order, the velocity was about 4 miles an hour. I found it, however, impracticable, on so contracted a scale, to preserve due tightness in the packing of the wings in the cylinder for any length of time. This defect determined me to resort again to the reciprocating engine."

In the same letter he describes another experiment as follows:

"The unsuccessful experiment in which I had, as above stated, been engaged in conjunction with Chancellor Livingston and Mr. Roosevelt, had taught me the



Another View of Col. John Stevens' Twin-Screw Engine

indispensable necessity of guarding against the injurious effects of partial pressure. [By this term, he alluded to the imperfect bracing between the cylinder and shaft.] And accordingly I constructed an engine, although differing much from those described in the specifications of my patents, yet so modified, as to embrace completely the principle stated therein. During the winter, this small engine was set up in a shop I then occupied at the Manhattan Works, and con-

tinued occasionally in operation until spring, when it was placed on board the above mentioned boat, and by means of bevel cog wheels, it worked the axis and wings above mentioned and gave the boats somewhat more velocity than the rotary engine. But after having gone some time, in crossing the river, with my son on board, the boiler, which was constructed of small tubes inserted at each end into metal heads, gave way so as to be incapable of reparation."

To overcome the tendency of the boat with a single propeller to turn in a circle, it was fitted with two screws, revolving in opposite directions. One of the ends sought by Stevens was a high-speed engine connected directly to the propeller shaft. The reason for the abandonment of the plan of screw propulsion is explained, writes F. B. Stevens, by an inspection of the rude workmanship of the twin-screw engine, as well as that of the boiler.

"There were no tools or competent workmen in America at that date to properly construct the steam engines and the boilers that he planned between 1800 and 1806. Success was impossible.

"When he finally realized this, unwearied by his attempts to introduce steam navigation, dating from the year 1791, he reverted to the paddle wheel, with its slow-moving engine, and with the boilers then in use, carrying steam at the pressure of two or three pounds above the atmosphere. He was engaged in building the "Phoenix" when Fulton arrived from Europe with the engine made for him by Watt in 1806, which, complete in all its details, and in these respects, far in advance of any engine that could then have been built in this country, achieved success."

The subsequent career of the Phoenix has already been described in the October number of The Journal. To detail the other engineering achievements of John Stevens and his sons, Robert L. and Edwin A., would require many additional pages. A brief outline, therefore, will be given.

The multitubular boiler was patented by John Stevens in the United States in 1791 and 1803 and in England in 1805. A boiler with vertical iron tubes was operated on an experimental locomotive in 1825. It is said that he established the first steam ferry in the world, between New York and Hoboken on October 11, 1811. In 1813 John Stevens designed an iron clad vessel with a "saucer-shaped" hull, to be plated with iron and carry a heavy battery.

In 1812 (five years before the commencement of work on the Erie canal) John Stevens addressed a memoir to the New York State Commission urging the immediate construction of a railroad instead of a canal. Though Stevens' plans and estimates were definite and their accuracy was afterward proved, the commission reported adversely.

The South Carolina Railroad, which when completed in 1832 was the largest railway in the world, was constructed on the plans of 1812.

Through his efforts in 1823, the Legislature of Pennsylvania passed acts for incorporating the Pennsylvania Railroad Company "to make, erect and establish a railroad on the route laid out (from Philadelphia to Columbia, in Lancaster County) to be constructed on the plan and under the superintendence and direction of the said John Stevens."

Three years later, Colonel Stevens constructed at his own expense a locomotive with a multitubular boiler, which was operated for several years on a circular track at the Hoboken estate. This was the first locomotive in America driven by steam and running on a track, of which there is any record.

Colonel Stevens died in 1838, aged eighty-nine years. His son Robert L. appears to have surpassed his father in engineering ability. It was he who sailed the Phoenix on the first ocean trip made by a steam vessel. The Philadelphia, which he built, had a speed of 8 miles an hour. The North American, built in 1832, attained a speed of 15 miles. "For 25 years after 1815 he stood at the head of his profession." In 1821 he originated the form of ferry-boats and ferry slips now in general use.

The "cam board" cut-off was invented by Robert L. Stevens in 1818, and in 1821 he adopted the walking-beam and improved it by making it of wrought-iron strap with a cast-iron center.

His work in the railroad field includes the design, while president and chief engineer of the Camden & Amboy R. R., of the present form of rail; the "hook-headed" spike, substantially the present railroad spike; and the "iron-tongue," developed into the fish-plate.

Edwin A. Stevens appears to have followed the line of business more closely than engineering, though he also is credited with several engineering achievements. Space will not permit any description of his work other than to say that he was active in organizing and operating the Camden & Amboy R. R., in making with his brother Robert improvements in steam navigation, in introducing iron armor for warships, and in devising methods of attack and defence for ironclads. He died in 1868, in his will making provision for the endowment of Stevens Institute of Technology, in Hoboken.

NECROLOGY

LEWIS CLESSON GROVER

Lewis Clesson Grover died at Hartford, Conn., September 30, 1909, after a long illness. He was born November 26, 1849, at Springfield, Mass. After an ordinary school education there, he acted as apprentice at the Norwalk Iron Works, Norwalk, Conn., for three years; after seven years' service with this company, serving for short periods with the Winchester Repeating Arms Co., New Haven, Conn., C. W. Lacount of Norwalk, Conn., Smith & Wesson, Springfield, Mass., and F. C. & A. E. Rowland, New Haven, Conn.

He became general manager of the Whitney Arms Company, New Haven, Conn., about 1880, holding this position until 1886, when he went to Hartford as assistant superintendent of the Colt's Patent Fire Arms Mfg. Co. He was soon promoted to the office of superintendent, and later to that of general manager. In 1902 he was elected president and a director of the company, at the same time becoming president of the Colt's Arms Co., of New York. Because of ill health he was finally compelled to relinquish to others the active duties of management, and in January resigned the office of president, the same meeting making him chairman of the boards of directors of both corporations.

Mr. Grover served as a member of the common council board of Hartford and as park commissioner. He was a prominent Mason and a member of the Hatchetts Reef Club. He entered this Society in 1890.

ROBERT HOE

Robert Hoe, head of the firm of Robert Hoe & Co., of New York and London, was born in New York, March 10, 1839, and was educated in public and private schools in this city. He was grandson of Robert Hoe of the hamlet of Hoes, Leicestershire, England, who began the manufacture of printing machines in New York in 1803, constructing and introducing into America the first iron and steel machines.

Mr. Hoe at an early age entered the printing factory established by his grandfather, and devoted his life to the improvement and develop-

ment of printing machinery. He developed the rotating-cylinder type of press to the present double-octuple press capable of printing, pasting, folding and delivering more than 150,000 16-page newspapers per hour. He also invented greatly improved processes of printing in colors, and is the author of several books on printing and binding.

Mr. Hoe always resided in New York, though his business interests were almost as great in London, and identified himself with its interests and prosperity. He was one of the founders of the Metropolitan Museum of Arts, founder and first president of the Grolier Club, and a member of the Engineers', Union League, Century, Players' and Fencers' Clubs. He joined The American Society of Mechanical Engineers in 1883.

Mr. Hoe died in London, September 22, 1909.

ROBERT B. LINCOLN

Robert B. Lincoln, president of the Waters Governor Company, Boston, Mass., died June 9, 1909, at his home in Waltham, Mass. Mr. Lincoln began his career in the Globe Works in Boston, afterwards serving throughout the Civil War. In 1868 he went to Cuba as chief engineer of the Maratanza, severing this relationship to become head draftsman at the South Boston Iron Works. In 1882 he designed the compound engine on the Cymbria at East Boston, Mass., and was subsequently connected with E. D. Leavitt of Cambridge, Mass., and later with the Portsmouth Navy Yard, where he remained nine years. At the time of his death, he had been president of the Waters Governor Company, for twenty-seven years, and during his life had held many other positions of trust which were filled with honor and fidelity.

PERSONALS OF THE MEMBERSHIP AM.SOC.M.E.

Arthur S. Blanchard, formerly with the Atha Steel Casting Co., Newark, N. J., is now associated with the Birdsboro Steel Foundry and Machine Co., Birdsboro. Pa., in the capacity of assistant general manager.

Dr. John A. Brashear addressed the October 19 meeting of the Engineers' Society of Western Pennsylvania, which was devoted to a discussion of Rapid Transit for Pittsburg.

Thurlow E. Coon has been appointed manager of the Detroit, Mich., office of the Ball Engine Co., and will at the same time handle a complete line of power plant equipment.

Claude E. Cox has accepted a position with the H. E. Wilcox Car Co., Minneapolis, Minn. Mr. Cox was until recently chief engineer and factory manager of the Interstate Automobile Co., Muncie, Ind.

R. G. Davis served as acting-quartermaster on the Clermont II during the Hudson-Fulton Celebration.

An article on Correct Metal for Castings, by Almon Emrie, was published in the October 7 issue of *The American Machinist.*

W. S. Giele, until recently superintendent of the plant of the Stoever Foundry and Mfg. Co., Myerstown, Pa., has severed his connection with that company. Mr. Giele is devoting his time to special work, and is living at New Brighton, S. I.

Warren W. Gore, formerly vice-president of the Gas Power Mfg. Co., Seattle, Wash., is now in charge of the experimental department of the Fairbanks-Morse factory in Beloit, Wis.

Chas. H. Green, member of the firm of M. A. Earl & Co., is now located at the Carthage, Mo., office of the company. He was formerly at the Muskogee, Okla., office.

An article on Production and Waste of Mineral Resources by Dr. J. A. Holmes, was published in the October 2 number of *The Mining World.*

Alfred Noble has been appointed consulting engineer to the Board of Water Supply, New York.

Harold L. Pope has become associated with the Matheson Motor Car Co., Wilkes-Barre, Pa., as engineer. He was formerly general manager of the Toledo Motor Co., Toledo, O.

Prof. Walter Rautenstrauch has contributed an article on An Investigation of Strength of Crane Hooks, to the October 7 issue of *The American Machinist.*

J. G. Clifton Sewell has become identified with the United Engine and Foundry Company, Pittsburg, Pa. Mr. Sewell was formerly associated with the Tennessee Coal, Iron and Railroad Co., Pittsburg, Pa.

G. B. Shipley contributed an article on A Comparison of the Various Processes of Preserving Timber, to the October 14 number of *Engineering News.*

Edward S. Smith has been appointed instructor in mathematics at the University of Virginia, University, Va. Until recently he was instructor in mechanical drawing in the School of Mines and Metallurgy of the University of Missouri, Rolla, Mo.

J. F. Taddiken, Jr., has been transferred from the Chino, Cal., branch of the American Beet Sugar Co., to the Rocky Ford, Colo., branch.

Dr. C. J. H. Woodbury is the author of a Bibliography of Cotton Manufacture, recently published.

EFFICIENCY TESTS OF LUBRICATING OILS

By Prof. Frederick H. Sibley, University, Ala.
Member of the Society

The tests described in this paper were made at the Case School of Applied Science, Cleveland, O., and had for their object:

a To determine the relation between the viscosity and the wearing and lubricating qualities of the oils.

b To determine the effect of the constituents of the various oils on the lubricating qualities.

2 Twenty-two oils were tested, the method of procedure being to find the chemical composition and viscosity of each oil and then to use it as a lubricant in a journal bearing. The temperature and frictional resistance were observed for a given length of time under a known load and speed. Previous experiments have left the question of the relation between viscosity and friction rather unsettled, but it is probable that if the load selected is a suitable one for a given oil then the friction will increase if the viscosity is increased. There seems to be no positive relation established between the viscosity and the wearing qualities of oils.

3 The lubricating quality of an oil is determined by its ability to maintain a continuous film over the lubricated surface, keeping the rubbing parts from direct contact. The coefficient of friction is the frictional resistance to motion of the journal, in pounds, divided by the load on the journal. The viscosity of an oil is measured by its resistance to flow, a strong resistance to flow indicating a high viscosity.

4 The apparatus used in these tests is shown in Fig. 1.[1] The pulley *D* on the shaft *B* is driven from a countershaft, having tight and loose pulleys. The journal *E*, upon which the tests were made,

[1] This machine was designed and built by Prof. C. H. Benjamin.

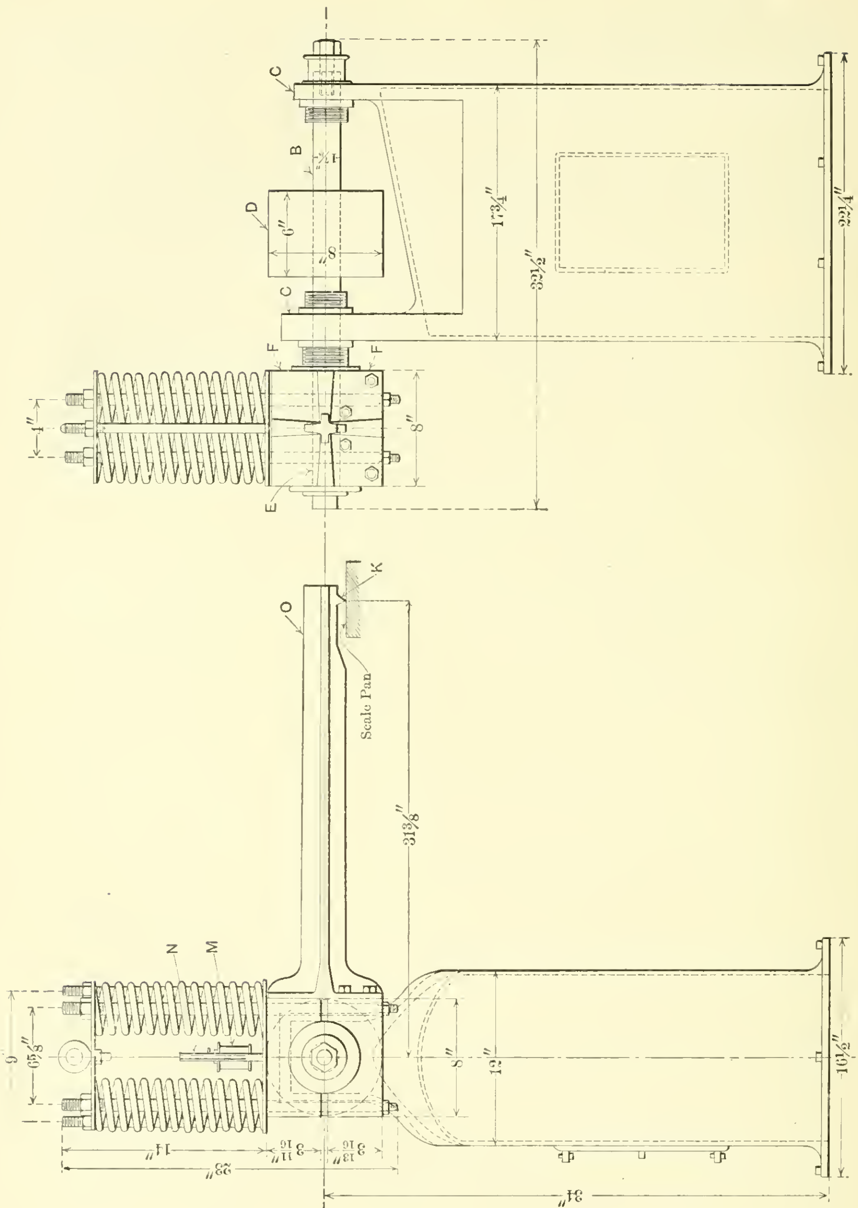


FIG. 1 APPARATUS USED FOR TESTING THE EFFICIENCY OF LUBRICATING OIL

is 8 in. long and 3.22 in. in diameter. Around the journal fits a babbitted sleeve, which is split in the middle, the upper half having oil grooves diagonally across it and intersecting in the middle in the form of a letter X. At the intersection of these grooves is the hole for the admission of oil. The lower half of the sleeve is without oil grooves. The sleeves are held in position on the journal by the cast-iron blocks *FF*. A collar at the back, next to the bearing *C*, and a washer and nut in front, prevent an endwise motion of the collar and sleeves, while allowing free rotation. The load is applied to both sides of the journal at the same time by compressing the springs when the nuts at the top of the springs are screwed up. Under ordinary working conditions the load is applied to but one side of the journal. These experiments therefore do not conform to actual conditions of pressure and wear, but as the results are comparative they are as fair to one oil as another in this respect.

5 The springs were calibrated before the tests by compressing them to a length of 11½ in., observing the load and then making this length the same for all the tests. The lever arm *O* was fastened to the upper block and its outer end was fitted with a knife edge which rested on a scale pan. The lubricant was fed through a sight-feed oil cup at *M*. The temperature of the bearing was determined by means of a thermometer inserted in an oil well at *N*. The machine was driven by an electric motor and the speed kept practically constant at 500 r.p.m. by means of a water rheostat.

6 The tests were conducted as follows, great care being taken to keep the conditions as nearly constant as possible for all the oils: The journal and sleeve were first cleaned with coal oil (kerosene) and rubbed dry with waste. The machine was then put together and the factor known in these tests as the lever-arm constant was determined. This was found by resting the knife edge *K* on the scale pan and rotating the journal first to the right and then to the left with no compression in the springs. The average of these readings gave the constant weight of the arm on the scales. Then the frictional resistance of the machine at any instant was measured by the difference between the scale reading at that instant and the lever-arm constant. After the constant had been determined the springs were screwed down to a length of 11½ in., giving a load of 1302 lb. for the whole bearing.

7 The oil cup was partly filled and the oil kept at a constant level so as to regulate the flow to a constant value of eight drops a minute. The machine was then started, and the bearing tempera-

ture, room temperature and scale reading were observed every ten minutes and the results entered on the log sheet of the tests. The oil feed and the speed of the machine were also adjusted from time to time and kept practically constant. At the end of two hours the oil supply was shut off and the run continued under the same conditions until the friction and temperature of the bearing indicated that the oil had given out.

8 The results of the tests are shown graphically by the diagrams in Figs. 2, 3 and 4. The horizontal scale shows the time in hours from beginning to end of test. The full lines were found by taking the bearing temperature on the vertical scale and the dotted lines were plotted by using the coefficient of friction on the vertical scale. The chart therefore shows the temperature, coefficient of friction and wearing qualities of every oil tested.

9 The coefficient of friction from which the dotted lines were plotted = journal friction ÷ load. For the machine used in these tests, this equation becomes

$$\text{Coefficient of friction} = \frac{(\text{scale reading} - \text{lever arm constant})\ \dfrac{\text{lever arm}}{\text{radius of journal}}}{\text{load}}$$

The scale reading is taken from the log sheets of the test.

The lever-arm constant was equal to 13.656 for this machine.

The length of the lever arm was 31.625 in.

The radius of the journal was 1.61 in.

The load on the journal was 1302 lb.

10 In the case of the castor oil, where the coefficient of friction at the end of two hours was 0.024 (see chart), by substituting in the above formula and transposing, we have:

$$\text{scale reading} = 0.024 \times 1302 \times \frac{1.61}{31.625} + 13.656 = 15.25$$

The scale reading being the known factor, the coefficient of friction was calculated for intervals of ten minutes corresponding to the time of the readings.

11 Table 1 gives the result of the chemical tests together with the data not found on the diagrams of Figs. 2, 3 and 4. The constituents of the oils, shown in Column 4, were found by distillation, each constiuent having a different temperature at which it separated from the oil. Nos. 1, 2 and 3 are simple oils; all the others

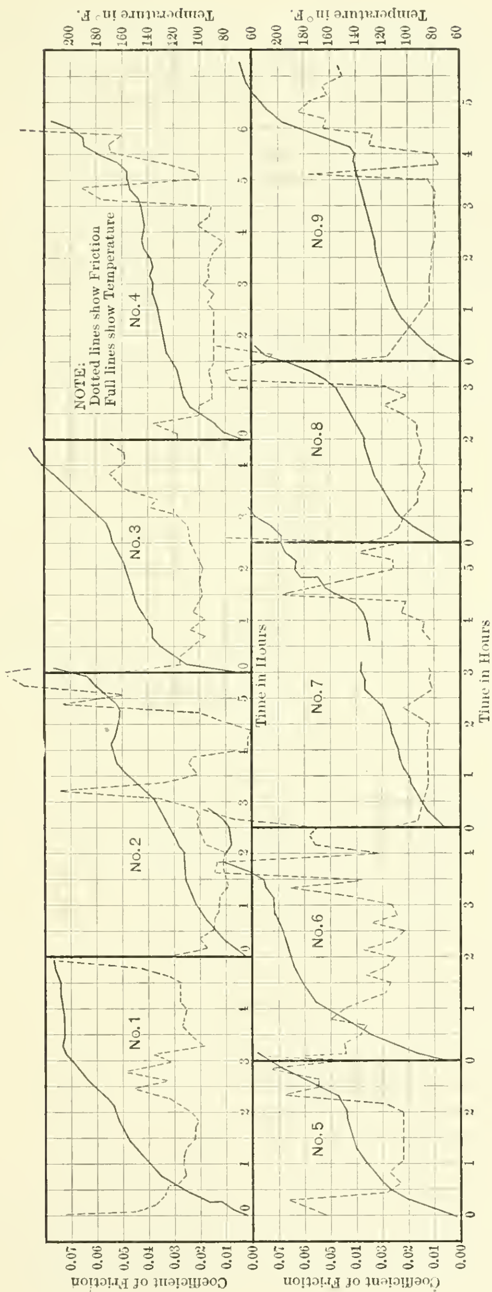


FIG. 2 CURVES OF FRICTION AND TEMPERATURE OBTAINED IN TESTS 1 TO 9

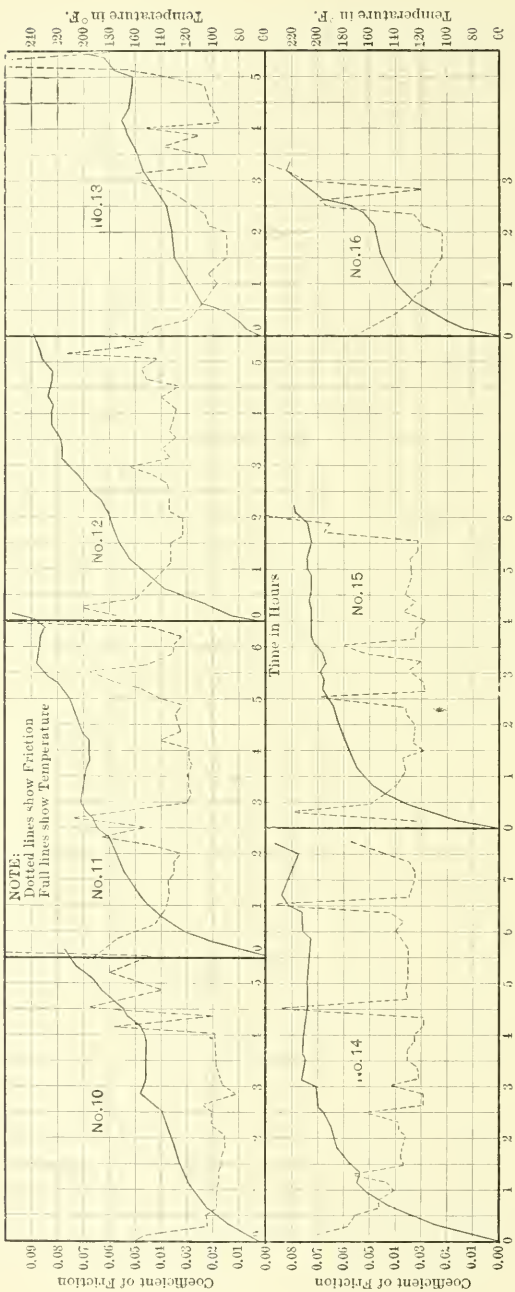


FIG. 3 CURVES OF FRICTION AND TEMPERATURE OBTAINED IN TESTS 10 TO 16

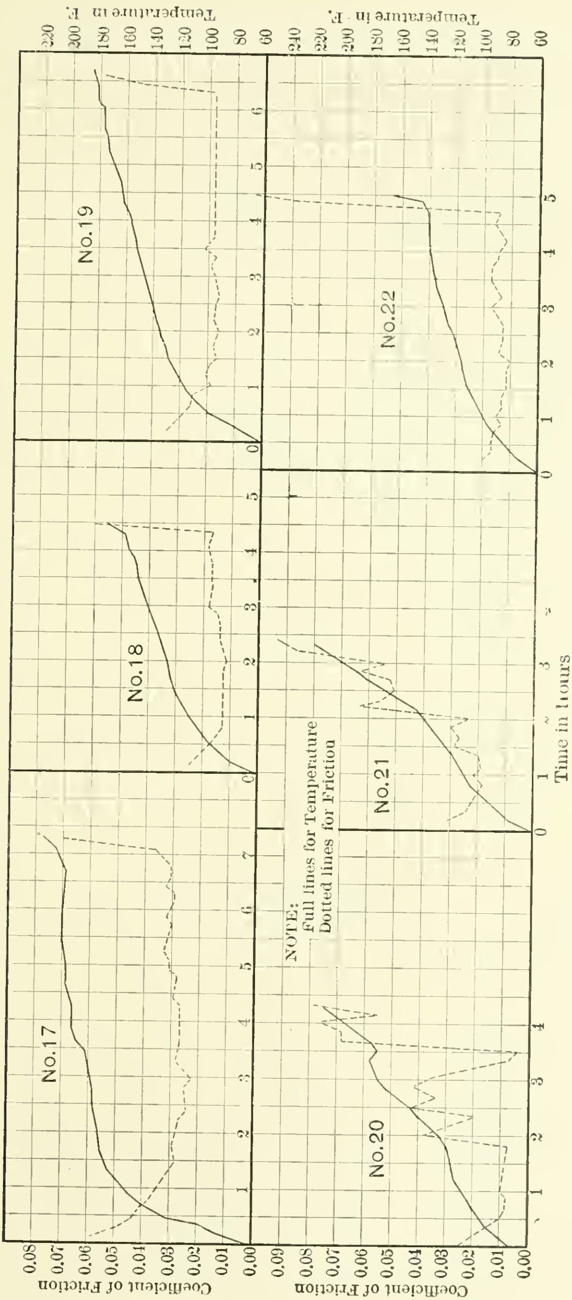


FIG. 4 CURVES OF FRICTION AND TEMPERATURE OBTAINED IN TESTS 17 TO 22

TABLE 1 CONSTITUENTS OF OILS AND DETAILS OF TESTS

No.	Kind of Oil[1]	Principal Constituents	Specific Gravity	Saponification Number	Viscosity	Flash	Fire	Oil Feed (8 drops per min.)			Endurance Test		
								Hours Feed	Max. Coef.	Max. Temp.	Hours Run	Max. Coef.	Max. Temp.
1	Pure castor (vegetable source)	....	15B	181	104 at 210°	.....	.....	2	0.0467	165	2.55	0.0740	215
2	Pure sperm (animal source)	....	30B	390	192 at 70°	.....	.....	2	0.0212	113	3.30	0.0960	214.5
3	Rape seed (vegetable source)	....	24B	324	108 at 150°	.....	.....	2	0.0278	154	2.24	0.0561	230
4	Engine No. 32789	Nos. 4 to 17 inclusive have for their principal constituents one of the four hydro-carbons C_nH_{2n+2}, C_nH_{2n-4}, C_nH_{2n}, C_nH_{2n-2},	26.6B	0	163 at 70°	378	432	2	0.0373	126	3.06	0.1109	212
5	Machine No. 32631		20B	0	472 at 70°	360	400	2	0.0656	146	1.10	0.1183	216
6	Capitol cyl. No. 32790		22B	10	123 at 212°	483	553	2	0.0496	186	2.50	0.0977	250
7	Dynamo No. 32,792		34B	0	86 at 70°	347	394	2	0.0156	111	2.55	0.1308	220
8	Union thread cutting No. 1		....	53	Low	200	230	2	0.0278	130	1.48	0.0920	216
9	No. 75		....	18		145	197	2	0.0335	121	3.12	0.0619	227
10	15° cold-test lub. No. 18		27B	18	480 at 70°	168	199	2	0.0457	129	3.35	0.0992	212
11	No. 74		....	25	....	267	318	2	0.0723	170	4.35	0.1260	250+
12	Model cyl. No. 14		28.6B	19	135 at 210°	258	310	2	0.0694	178	3.30	0.0741	236
13	Eldorado engine No. 37		....	......	....	179	203	2	0.0429	129.5	3.27	0.1430	196
14	Filtered cyl. No. 72		29.6B	19	105 at 210°	246	284	2	0.0769	182	4.10	0.0902	218
15	Shield cyl. No. 6		28.6B	19	130 at 210°	178	309	2	0.0533	187.5	5.40	0.0826	232
16	Summer lub. No. 38		29.4B	19	120 at 250°	205	228	2	0.0515	152	1.30	0.0817	244
17	Amer. valve No. 17		27.6B	30	125 at 210°	285	382	2	0.0581	172	5.20	0.0704	214
18	Penn.	$C_n H_{2n}$	0.861abs.	0	37.6 abs.	.....	.....	2	0.0241	126	2.30	0.0619	171
19	Penn.	$C_n H_{2n-2}$	0.868abs.	0	87.4 abs.	.....	.....	2	0.0326	134.5	4.35	0.0581	184
20	Texas	$C_n H_{2n-4}$	0.923abs.	0	75.3 abs.	.....	.....	50m+50m	0.0439	144	2.15	0.0855	228
21	Penn.	$C_n H_{2n}$	0.850abs.	0	37.6 abs.	.....	.....	2	0.0297	140	1.20	0.0921	220
22	Penn.	$C_n H_{2n}$	0.861abs.	0	37.6 abs.	.....	.....	2	0.1035	116	3.00	0.1039	165

[1] Nos. 4 to 17 inclusive are standard products made from Ohio and Pennsylvania products.

have for their principal constituent one of the group of hydrocarbons $C_n H_{2n-4}$, $C_n H_{2n-2}$, $C_n H_{2n}$, $C_n H_{2n+2}$. The purpose was to compare each oil having one of the above hydrocarbon radicals with the first three oils given, and thus to determine the relative effect of these hydrocarbon constituents.

12 The specific gravity is given in degrees Beaumé and is determined by the following formula:

$$\frac{130}{\text{specific gravity}} - 130 = \text{degrees Beaumé}$$

13 The viscosity was determined with a Saybolt viscosimeter. It is expressed in the number of drops per minute that will pass through a given orifice at a definite temperature. The table shows viscosities taken at varying temperatures. It is not practicable to take these viscosities all at the same temperature. The viscosity of an oil like No. 7, for example, if taken at a temperature of 210 deg. would not really represent the viscosity of that oil as it was never intended to be subjected to such a high temperature.

14 Column 5 gives the saponification number. This is the number of milligrams of KOH (potassium hydrate) that will be taken up by one gram of the oil. In other words, it is the number of milligrams of KOH per gram of oil that would be required to make soap. For example, in castor oil, which is a compound having a glycerine for a base, combined with a fatty acid, if KOH is added under the proper conditions, being a stronger base than the glycerine, it will drive out the latter and combine with the fatty acid in the proportion of 181 mg. to one gram of the original oil.

15 In an engine cylinder at a high pressure and temperature an oil may become decomposed, and the fatty acid being liberated will attack the metal of the cylinder. It follows therefore that the higher the saponification number of an oil, the greater the quantity of acid that may be liberated to attack the cylinder walls. It can hardly be said that the present tests show any definite relations between the viscosity and the bearing and lubricating qualities of the oils. They are interesting rather as showing the behavior of the particular oils in question in comparison with the relatively familiar examples numbered 1, 2 and 3.

16 The viscosity of an oil does affect its lubricating quality in the following way: if the oil is adapted to the load put upon it, then the lower the viscosity the better lubricant it will be. With heavy oils some work will be absorbed in overcoming the internal resistance

of the oil itself. The load should conform to the character of the oil, a light oil being unsuitable for a heavy load. The reason why some of the oils in these tests broke down early was because the load was too heavy for them.

17 Oil No. 21 contained paraffine and the injurious effect of this substance on the lubricating quality of the oil is shown by the chart for that oil. Oils No. 18, 19, 21 and 22 are individual hydrocarbons separated by long continued fractional distillation from Pennsylvania and Texas oils. These oils have been found to belong to the series $C_n H_{2n}$, $C_n H_{2n-2}$, $C_n H_{2n-4}$.

18 The series $C_n H_{2n}$ may be regarded as representing the larger portion of the constituents of lubricating oils as made from crude petroleum. The higher vicosity of these hydrocarbons, which are relatively poor in hydrogen, is shown in the table. Professor Mabery has been led to believe from his examination of different varieties of petroleum and the separation of individual hydrocarbons, that in oils like those of Nos. 4 to 17 of the table the general composition is represented by the series $C_n H_{2n}$, $C_n H_{2n-2}$. They also doubtless contain smaller amounts of hydrocarbon poorer in hydrogen.

19 The chemical work of the tests was done under the direction of Prof. C. F. Mabery and the mechanical work by the writer and Mr. Horace Allen, a senior student at Case School.

ECONOMY OF THE ELECTRIC DRIVE IN THE MACHINE SHOP

By A. L. De Leeuw, Cincinnati, O.

Member of the Society

It is proposed to show in this paper the most salient points which affect the economy of the electric drive in the shop, and also, in a general way, the proper relation between the motor and the driven machine.

2 When the electric motor was first used in the shop, practically no other claim was made for it than that it saved power by obviating the losses in line and countershafts. Exaggerated statements were made of savings to be effected; and though it was proved later that many of these claims should be divided by a large factor, and that some should even be provided with the negative sign, these statements did a great deal of good by calling attention to the fact that great losses existed.

3 The writer knows of no way to determine the exact amount of these losses, but wishes to call attention to the fact that a method which has been employed quite frequently is entirely misleading. The method referred to is, to measure electrically or by indicator card the amount of power required to run all or a part of shop with and without machine load. The difference between the two readings is supposed to be the loss. That this is wrong becomes obvious as soon as one considers that the frictional load of every bearing changes with the amount of the load, and that the belt pull sets up bending and torsional strains in long lengths of shafting, which may cause losses much greater than the losses by journal friction.

4 The method of taking separate measurements of the work done by each machine individually, and totaling the result, is also wrong, as all machines do not require the maximum amount of power at the same time. To multiply the total by some fractional coefficient is merely a refined way of guessing. Statements have from

All papers are subject to revision.

time to time appeared, as to the amount of saving effected by the substitution of motor drives for line-shaft drives, but never with the positive statement that at the same time other changes were not made which might have some effect on the situation. This absence of reliable data is apparent all over the field of this subject, and it will therefore be impossible to say beforehand with any fair degree of certainty how much, if anything, can be gained by the conversion of a shop from a shaft to motor drive. It will be possible, however, to indicate points which should be kept in mind, and which are the controlling factors.

5 Economy is the art of obtaining the greatest output with the smallest outlay. To strike a balance between these two elements, outlay and output, is the work of the industrial engineer. In a great many cases, perhaps in the majority, there are not sufficient data to enable him to do this; his work then becomes hazardous and is on a level with that of the prospector. Many reputations are based on a stroke of luck and many have been lost by a single wrong guess. On the other hand, many hundreds of thousands, or more likely, millions of dollars have been lost to shop owners by listening to the lure of the enthusiastic engineer with more faith than data.

POINTS TO BE CONSIDERED

6 In considering the economical features, when converting a shop from shaft to motor drive, the following points should be kept in mind:

- *a* The nature of the shop.
- *b* The possible economies which may be effected by the installation of electric drive.
- *c* The first cost of such an installation.
- *d* The cost of its upkeep.
- *e* The cost per unit of power.

Though these are the main points to be considered in a preliminary investigation, they are by no means the only ones. They are specially mentioned here because their contemplation will naturally lead to the consideration of other points as well.

7 As the electric drive for the machine shop alone will be considered here, it may seem that the nature of the shop might have been left out of consideration. In the great majority of cases, however, a machine shop is of a dual nature. A foundry or blacksmith shop, or perhaps, a plating shop is connected with the establishment; or

warehouse and yard service may form a considerable portion of the operations. The yard service of a plant may be of an elaborate nature, while the machining operations are of a simple nature. It may be that the machine-shop operations cannot be improved enough by the change to electric drive to warrant its installation, yet the gains to be made by converting yard cranes and other similar apparatus to electrically driven apparatus may be so great as to make it advisable to change the mode of driving of the entire plant.

8 As to the possible economies which may be effected by a change of drive, this involves so many considerations that nothing but an exhaustive study of the entire plant in all its aspects will clearly show what may be accomplished. Though at one time the only economy considered was the saving of power, it is now well recognized that this is by no means the only nor the most important economy resulting from a conversion to electric drive, and that such a conversion may even be highly economical, though there be an actual loss in power consumed.

9 To illustrate: practically all of the work done in a machine shop, for which power is used, is the removal of chips. The writer has in mind a shop where an average of 9 tons of metal is daily fed through the shop, to be made up into high-grade machinery. This metal is for the greater part cast iron, with a minority of steel and a small percentage of bronze and other metals, just as in most machine shops. The total of chips removed amounts to less than 15 per cent or 2700 lb. of metal in a nine-hour day, making 300 lb. per hr., or 5 lb. per min. This shop uses an average of 225 h.p., which is 45 h.p. per min. for each pound of chips removed. Figuring that all the chips are steel, this would mean that the shop requires about 12 h.p. per cu. in. of steel removed. It should be noted that this shop is to a large extent electrically driven, and otherwise as well or better equipped than the majority of machine shops. The power costs about $40 per h.p. per year, or a total of $9000, which includes steam for heating, however.

10 Figuring that all of this amount is spent for power, and that half of it could be saved by some other mode of driving, then the total possible gain would be $4500 per year. This shop employs about five hundred men, so that the gain would be $9 per man per year. An establishment of this kind and size delivers a product of about $2000 per man per year. If the installation of a new mode of driving could increase this output only 5 per cent, then the gain per man per year would be $40, or more than four times the gain which

can be made by cutting the power consumption in two. Obviously then, the problem is to increase the amount of chips made in a given shop, and not to diminish the amount of horsepower for a given amount of chips. This phase of the subject will be treated more extensively later.

11 As to the first cost of installation, though it may be beyond doubt that a change in the mode of driving might effect economies yet it remains to be shown that these economies give a good return on the investment, and further, that this same investment could not be placed in another direction to better advantage. What is true when a shop is to be converted from one drive to another, is also true when a new plant is to be built. Directors of industrial undertakings have frequently been criticised for apparent lack of progress, when a close analysis might have shown other more crying needs for the investment of the capital at command. Though the shop of an industrial undertaking may be the only place where its product is made, it may not be the only place where its money is made. And even should the shop be beyond doubt the best place to invest the money on hand, it remains to be shown that the proposed change of drive will bring better returns than improvements along other lines. This question will also be dealt with later.

12 The probable cost of upkeep must also be thoroughly investigated, especially as this is likely to be under-estimated unless one goes fully into details. In considering the probable economies, this cost of upkeep has to be estimated and deducted from the gross gains; but the same item appears again in the form of disturbance of operation, when it is much harder to estimate it. This must be done as well as possible, however, before reaching a final conclusion. These disturbances make themselves especially felt the first few years after making the change.

13 It is further true that most radical changes are made at a time when there is a heavy demand on the shop, either because it is thought that the output can be increased by the contemplated changes, or because the size of the power plant has not kept step with the growth of the rest of the plant, or because at such times of business prosperity, money can be easily obtained for such changes. Whatever the reasons, the fact has been fairly well established; and a change at such a time must be doubly hazardous, not only because it may fail to accomplish the desired increase of output, but because it may actually prove to be a source of disturbance, and reduce the output instead of increasing it.

14 As to the cost per unit of power, this should enter into the preliminary considerations, as it will determine to a large extent the kind of current to be used, and this may have a decided effect on the final economy of the system as applied to the shop. Attention will again be directed to the foregoing items later in the paper.

SAVINGS EFFECTED BY ELECTRIC DRIVE—INCREASED OUTPUT

15 The savings effected by driving the shop electrically may be classed under two heads: increased output and less expense. Whether savings can be effected by increasing the output depends on so many and such varied items that it seems best to show them first in an elementary way, by considering a single machine under a set of assumed conditions.

16 Let us take for example a 12-ft. boring and turning mill, used in a shop devoted to the manufacture of a single line of product and having enough machines of each kind to allow each machine to be devoted to a very limited line of operations. Suppose the machine under consideration to do nothing but turn up large rings, ranging in diameter from 12 ft. to 8 ft., and further, that a great number of rings of each size are to be turned up in each lot, so that the amount of time lost in setting the machine for the different kinds of work becomes negligible. Let it be further supposed that the machine is provided with a number of speeds in geometrical progression, with steps of 25 per cent, and that there is one speed which happens to correspond to the proper speed for the material used and for a diameter of 12 ft. This is supposing a set of conditions as good as can be expected in the ordinary commercial machine.

17 Under these conditions, the low speed must be used for all rings from 12 ft. down to 9.6 ft., and the next higher speed for all rings ranging from 9.6 ft. down to 8 ft. Supposing that the number of all rings of the same size is the same, it follows that the machine runs $\frac{6}{10}$ of the year on the lower speed, and $\frac{4}{10}$ of the year on the higher one. Allowing $\frac{1}{4}$ of the total time for chucking work, removing it, changing tools, etc., there remains $\frac{3}{4}$ of the year spent in removing chips. The machine removes chips, therefore, at the lower speed during $\frac{9}{20}$ ($\frac{6}{10}$ of $\frac{3}{4}$) of the year, and $\frac{6}{20}$ ($\frac{4}{10}$ of $\frac{3}{4}$) of the year at the higher speed. This higher speed might be called 12, and the lower speed 9.6. A measure for the amount of chips removed, and, therefore, for the number of pieces turned up, would then be the amount of time multiplied by the linear speed of the tool. This is not exactly correct, but near enough for a mere illustration.

18 So far, however, an expression has been found only for the number of revolutions of the machine. In order to reduce this to linear speed, we must consider the fact that the higher speed is the proper speed for a diameter of 9.6 ft., and the lower speed for a diameter of 12 ft. If the machine were to run all the time at the speed corresponding to the diameter to be turned up, the total output for the year could be expressed by the time the machine is actually removing chips, which is $\frac{3}{4}$.

19 When running at the lower speed, however, the machine has the proper speed only when the diameter to be turned up is exactly 12 ft. At all other diameters, the speed is too low. The effect is the same as if the machine were running all the time at the lower speed, and all the work were of a diameter of the mean between 12 and 9.6, or 10.8. Therefore, when running on the low speed, the output runs down from $\frac{9}{20}$ to $\frac{81}{200}$. Similarly, the output of the machine, when running at the higher speed, has been reduced from $\frac{6}{20}$ to $\frac{55}{200}$, and the total from $\frac{3}{4}$ to $\frac{136}{200}$, or a reduction of nearly 10 per cent. Now if this machine were driven by a variable-speed motor, it would be possible to find a proper speed for every size of ring to be turned up, and the production might be increased from 136 to 150, or a gain of nearly 11 per cent.

20 Merely to say that there is a gain in production of 11 per cent is perhaps sufficient to prove that under certain conditions a change from belt to motor drive may be profitable, but it is in no way a measure of the amount of profit. If, for instance, the machine is capable of taking care of all the work in the shop, then the only gain is in the wages of the operator; if, on the other hand, there is more work than the machine can take care of, then the increased production of the machine may mean a corresponding increase in the production of the entire shop, improved deliveries, and the avoidance of a great deal of confusion, of which the money value may be many times greater than the mere saving in wages.

21 In the foregoing example, the advantage gained is entirely due to the fact that a variable-speed motor was attached to the machine. This is by no means, however, the only reason why the change to electric drive may increase the efficiency of a machine. The electric drive may enable one to place the machine in a more convenient position, or bring it under a crane; or it may be the means of giving the machine more power than it could have with a belt drive; or again, it may be the means of doing away with some harmful conditions which have diminished the machine's efficiency.

Among such circumstances may be mentioned the slackness of belts due to weather conditions, or to the varying loads placed on an upper floor, making the belts from pulleys attached to the under-side of this floor either too loose, having been adjusted at a time when the load on the upper floor was light; or too tight, owing to adjustment at a time when the load on the upper floor was heavy. Then there is the convenience of altering speed if a machine has a motor or a convenient gear drive, when the operator might forget that there is such a thing as a change of speed for varying conditions of work, if he had to shift a belt. An almost unlimited number of considerations affect the result to be obtained from the application of a motor to a machine tool; so that it is almost impossible to forecast the economy which will result from such a change, though it may be perfectly possible to say that the change will be beneficial to some extent.

22 The fact that the change from one style of drive to another is practically always accompanied by some other changes, either in addition to, or as a result of the change of drive, makes it impossible to show by data how much gain is the result of this change. Under very definite conditions, such as were supposed in the example given, it may be possible to calculate these gains beforehand, and even to verify the calculations by the actual results, but in the vast majority of cases neither calculation nor verification is possible. For this reason, this paper is confined to pointing out in which respects, and under which conditions profits may be expected. Such profits will appear either in increased output or in the curtailing of expenses.

HOW ELECTRIC DRIVE EFFECTS INCREASED OUTPUT

23 We will now consider more in detail the economic advantages mentioned in the foregoing paragraphs. Fig. 1 shows the main points in which an increase in output may be expected from the substitution of electric drive for shaft drive. The electric drive will show its effect on individual machines (provided they are individually motor-driven), on the handling of the work in the shop, on the light and cleanliness of the place, on the possibility of making changes in the arrangement of the shop when needed, and last, but not least, on the individual effort of the operator.

24 *More power.* The greater output of individually motor-driven machine tools is due to a number of items, shown in the diagram. The first item, more power, is especially prominent in heavy tools.

The power of cone-driven machines is limited by the belt speed, and by the width possible, considering that the belt has to be shifted. It might be said that a single-pulley drive has no such limitations; but on the other hand the single-pulley drive does not lend itself to fine gradations of speed, especially in heavy machinery. Further, such a drive would take up a great deal of space, would be very costly, and would be extremely awkward to handle, unless auxiliary mechanism were provided to do the shifting of the heavy gears, which is

- *Effects of Motor Drive*
  - *On Individual Machines*
    - *More Power*
    - *Overload Capacity*
    - *Freedom from Belt Troubles*
    - *Fine Gradations of Speed*
    - *No Shifting of Belts*
    - *Possibility of Increased Speed with Proportional Increase of Power*
  - *Handling of Work*
    - *Electric Cranes, Hoists, etc.*
    - *Lifting Magnets*
    - *Magnetic Separators*
    - *Magnetic Chucks*
    - *Magnetic Clutches*
    - *Stopping and Starting Devices*
    - *Signal Systems*
  - *Light in the Shops*
  - *Elasticity of Shop Arrangement*
  - *Effort of Operatives*

Fig. 1 Showing the Advantages of Electric Drive

a further source of expense. The electric drive, on the other hand, would allow of a motor with a certain amount of variation of speed, which, combined with a few gears, would give all the variation obtainable with the cone pulley, and by much finer gradations. This is so well recognized at the present time, that very few heavy machines are built to order with a cone drive.

25 High-speed steels made an increase of power imperative for some of the heavy machines, and for some of the lighter ones as well.

In a number of cases, it was found that the frame of the machine, as well as most of its mechanism, was strong enough to stand this increase of power, but that it was practically impossible to substitute larger cone pulleys without rebuilding the entire machine; in all such cases, the electric motor has proved to be the solution of the problem.

26 *Overload Capacity.* The electric motor not only makes it possible to give more power to the machine, but it gives it a reserve capacity that a belt-driven machine cannot have. For instance, a casting has to be turned up: it has a swelling where the seam of the parting is, and the amount of metal at this one point is too much for a single cut; the machine stalls. If the machine were motor-driven the overload capacity of the motor would carry the cut past this point, without harming the motor. In other words, a motor acts on a machine tool somewhat as a flywheel acts on an engine. Before electric drives were known, the power of the machine tool was almost always its weak point; after electric motors were applied to existing machines, it was the frame of the machine which had to be treated with consideration.

27 *Freedom from belt troubles.* The omission of belt troubles is one of the strongest points in favor of the electric drive. During an investigation of a large Western railroad shop by the writer, this point was shown with exceptional clearness. Practically all machine operators "nursed" their jobs because they had to wait too long for the chief millwright, who thought he was the only man capable of putting on or correcting a belt in the proper manner. Out of consideration for the machine tools, this man would put on belts from ½ in. to 1 in. too narrow. The combination of these two pieces of foolishness reduced the output of the belt-driven machines fully 50 per cent where heavy cuts had to be taken, and reduced the output of the entire machine department at least 10 per cent. It might be said that the management should have corrected this evil, and so it did, but only after the evil had existed for a great many years. Conditions such as these are the outcome of growth, and are generally not found out until the shop becomes too small for the work to be done and the management begins to cast around for means to increase the output.

28 Belt troubles are caused by so many conditions that a shop is rarely free from them. It was observed at the shops of a machine-tool concern in the middle West, that the output of their milling machines was increased 25 per cent by driving them by electric motors, though no further changes were made. The observation

deserves attention, because while some of the machines were changed to electric drive, other similar machines were left with belt drive, and there is a clear chance for comparison. The main reason for the increased output was supposed to be the avoidance of belt trouble. These milling machines were located on the first floor. The second floor was also used for a machine shop, and was at times heavily loaded with finished and unfinished stock; this variation in loading causing a variation in the deflection of the upper floor, that made it necessary to keep the belt quite slack, for fear it might be too tight when the upper floor was not loaded. Weather conditions have a similar effect; especially where there are rapid changes in humidity. The effect is to lower the capacity of the machine by a large percentage.

29 *Fine gradations of speed.* Another reason for the greater economy of motor-driven machines is that finer gradations are obtainable with a motor drive. Of course, this benefit is derived only from a variable-speed motor. When attention was called to this feature earlier in the paper, nothing was taken into consideration except the fact that it would be possible with the variable-speed motor to obtain a speed in accordance with the material to be cut, and with the diameter of the work or of the cutter. However, there is more than this to be considered. A lot of castings are seldom or never of uniform hardness. This being the case, it is quite natural for the operator to set his machine for the hardest piece in the lot, and it may well happen that he strikes the hardest piece first. Where he has simple means for varying his speed, he will be governed entirely by the hardness of the piece on which he is doing work.

30 *No shifting of belts.* The fact that no belts have to be shifted is [another cause of increased efficiency. The machine operator who shifts belts for pleasure has yet to be found. Besides, where the ceiling is high, it is not easily possible to shift a belt without the aid of a long stick; and this stick is generally somewhere else. The amount of time lost in hunting for the stick, and in the operation of shifting the belt, may be quite considerable in itself, especially in shops where small lots are the rule and where it does not pay to perform only one operation at a time, so that a single piece must receive all the operations of a certain machine before it is taken out of it.

31 But worse than the loss of time in shifting belts is the fact that this shifting is generally entirely neglected, and all the various operations are carried out at the speed of the slowest. There are cases

where the gain due to this feature of the motor drive may be negligible, and there are other cases where this gain may be a large percentage.

32 *Increase in power with increase in speed.* Another point in favor of the motor drive, is the fact that it is possible to speed up a machine with a proportional increase in its power. This problem appears whenever a change is made from carbon to high-speed steels; and though most shops at the present time are provided with high-speed cutting tools, this is by no means true to such an extent that this point may be overlooked. There are few, if any shops where some operations are not done with carbon-steel tools, sometimes because high-speed steel has been overlooked, but more often because no benefits would be derived from it as the machine could not be run at a higher speed without cutting down the depth of cut or feed. In some cases, this can be corrected by putting a larger pulley on the line shaft; but in the majority of cases which have come to the attention of the writer, this could not be done without more elaborate changes.

33 Generally speaking, it is a small thing to increase the speed of a motor-driven tool without cutting down its torque. Not long ago a number of cases came to the attention of the writer, which put this matter to him in a very clear light. Some boring machines, used for boring holes out of the solid in steel bars, and using twist drills for this purpose, were supplied with high-speed drills; but it was found that the feed could not be increased, as the machine was run to the limit of its capacity. It was further found impossible to shift the belt to a larger step of the cone, thus giving more torque, as it was not practical to increase the speed of the machine without making extensive changes in the arrangement of the line shaft. A motor drive would have solved the problem and would have increased the feed from $\frac{5}{8}$ in. to $1\frac{1}{8}$ in. per minute. Such instances are by no means rare. It is this feature of the motor drive which makes it possible, in many cases, to get the full benefit of high-speed steels with old machines.

HANDLING OF THE WORK

34 *Electric cranes.* Electric current in a shop not only makes it possible to get more production from machines individually, but admits of a number of improvements in the handling of work. The electric traveling crane has become such a common aid in the shop that it is almost difficult to realize that it is only twenty years since it was new. It is also hard to realize that it is one of the possibilities

of the electric drive. The effect of the electric crane on the economy of the shop cannot well be over-estimated; though it is difficult to express in figures the amount of this economy. So much can be said, that only a few shops are over-supplied with cranes, while in a great number more cranes could be placed to good advantage. The installation of electric cranes or hoists in a shop is somewhat similar to the installation of compressed air. It is generally difficult to estimate beforehand with certainty the amount of savings to be effected, or to realize the various uses to which the apparatus will be put, but once a compressor is installed its capacity is soon exceeded; similarly, the electric crane is soon overworked.

35 The proper choice and installation of electric cranes and hoists is a separate branch of industrial engineering, though not generally considered as such. The best effects can be had only when the apparatus is taken into consideration with the placing of the tools in the shop, and the laying out of the shop buildings. Instances where the exact amount of savings effected was known even after the new apparatus had been installed for some time, are also rare, though not quite to the same extent as data about machine tools. The installation of a yard crane in a flask yard reduced the number of laborers from nine men to two and the crane tender. The installation of a small electric hoist, on a small traveler worked by hand, increased the output of a milling machine, besides doing away with the help of a laborer. It should be remarked here that the weight of the piece to be milled was too much to be lifted by hand, and that the time used for the operation proper was small. Instances of this kind are not rare and have come under the observation of almost any engineer connected with industrial establishments.

36 *Lifting magnets.* In line with electric cranes are lifting magnets, which are to be considered as an adjunct to the crane. They can often be used to good advantage for lifting plates, for loading and unloading pig-iron and scrap, for hauling small castings in quantities, and even larger castings provided their shape and the distribution of metal makes them adapted to this mode of handling, for lifting drop weights, and for a number of other purposes. Though no instances are at hand, it seems to the writer that a small lifting magnet could be used to good advantage for collecting chips at the various machine tools in a shop.

37 *Magnetic separators.* Magnetic separators, though more commonly used in the foundry, are used also in the machine shop for the complete separation of the chips of various metals. However,

they seem to be more in the nature of a luxury than of a necessity.

38 *Magnetic chucks.* This cannot be said of magnetic chucks, which make it possible to do quickly, conveniently and accurately a great many jobs which would be very difficult, if not impossible, without this piece of apparatus. Magnetic chucks are of special merit in combination with small planers, shapers, milling machines, lathes and grinders. Their economical value may range from a mere aid to the operator, to the means of doing a job which could not otherwise be done at all. It is generally easy to estimate the savings to be effected, as the time for ordinary chucking methods is well known, and the time for chucking by means of the magnetic chuck, is practically negligible; further, the amount of power used for the chucks does not need to be taken into consideration. They have their limitations and are not adapted to all or even to a great number of operations; but where they are applicable at all, they are of great value.

39 *Magnetic clutches.* Magnetic clutches seemed at one time destined to play a great part in shop economy. So far, however, they have been a disappointment. This seems to be partly due to inherent weaknesses of the magnetic clutch, but perhaps more to faulty construction, and especially to the fact that those who designed and developed the magnetic clutch did not quite clearly understand the requirements of the machine tools to which they were to be applied, and further, that those who had to apply the clutch to machine tools did not understand the peculiarities of a magnet. There never was the hearty coöperation that would make the magnetic clutch a success.

40 It would not be surprising to see the magnetic clutch come to the foreground once more and claim its own. There seems to be a field for this kind of apparatus in controlling mechanism of all kinds, as well as for braking the movement of a machine or a part thereof. Its peculiar value in this respect would be to give the operator the means for controlling his machine, by merely touching a button or turning a small switch. The magnetic brake is employed now, especially in cranes, indicating that there is nothing inherent in the magnetic clutch which makes it unfit for application.

41 Attention might be called here to the possibilities of the application of the magnet in its various forms to operations in the shop, and to functions in a machine tool. Magnets now are employed for holding small portable tools in position, and might be used for

vises and other handling devices. Further attention should be called to the possibility of using the motor itself as a brake, by short-circuiting the armature on a given amount of resistance.

42 *Stopping and starting devices.* In the previous paragraphs, mention was made of the possibility of applying the electric magnet for the purpose of controlling a machine. This might be called control from a distance though in the applications hinted at, the distance would be very small in most cases. There is no reason, however, why this distance could not be increased at will. As a matter of fact, a number of installations are in existence where electric devices (though not necessarily electro-magnets) are in use for this very purpose. They will be found especially in rolling mills, and other plants where given amounts of material have to be handled continuously. These devices enable the engineer to minimize manual labor, besides making the plant safer and the action more continuous.

43 *Electric signals.* Electric signal service in shops was well known before the electric drive was thought of, but it can be greatly improved where electric power is at hand, as lamps of different colors, placed in the shop, will transmit intelligence better and with less confusion than electric bells. The telephone would come under the head of electric signals, but it is not dependent on the use of current in the shop.

44 *Lighting.* One of the greatest blessings of the electric current in the shop is electric lighting. This is so generally acknowledged, and so universally employed, however, that it would be a waste of space to go further into this matter here.

45 *Elasticity of shop arrangement.* Another great benefit of the electric drive is elasticity of shop arrangement. Growing establishments had to be satisfied with arrangements of machinery which had no other point in their favor than that they were the only possible ones. It was often necessary to place departments where they should not be, simply because it was not possible to drive the machinery in them if they were placed elsewhere. The electric drive makes it possible to change the arrangement of the machinery, and the relative location and size of the different departments, according to the changing needs of the shop. This principle of changing the shop according to the work to be done, is carried to its logical limit in the system of floor plates and portable tools.

46 Besides making alterations in an existing arrangement possible, the electric drive also allows departments to be placed far

enough from each other to permit of extending each one separately, without interfering with the other departments. This was generally not possible with belt drive, as the distances became entirely too large. It was generally found necessary for large plants to have a multiplicity of engines. A number of the best known modern shops are witnesses to the advantage of electric drive in the matter of arranging buildings and departments. It is hardly necessary to mention that the established ideas in regard to shop arrangement had to be largely revised and that there is even now considerable uncertainty as to what is the best possible arrangement, but it is safe to say that there is little divergence of opinion as to what kind of drive will give the greatest possible elasticity, if elasticity is required or deemed advisable.

47 *Effect on operatives.* It was mentioned before that the variable-speed motor, applied to a machine tool induces the operator to experiment with the best possible speeds. There is, however, another way in which the electric drive affects the efforts of the men. It is nowadays well recognized that favorable conditions in regard to light, heat, sanitary conditions, etc., have their immediate effect on the output of the shop. These conditions cannot be ideal with a confusion of belts obstructing light and gathering and distributing dirt. Though in most electrically driven shops belts are not entirely absent, they are so few that their evil effects are reduced to a minimum.

RELATION OF FIRST COST TO DECREASED EXPENSES

48 Whether savings are effected by lessening expenses depends on the nature of the old installation and that of the new one.

49 The writer was at one time connected with a large manufacturing plant, spread over a large tract of ground, which in its general layout and operations is fairly representative of a great number of existing manufacturing plants. It was at that time steam-driven, as the motor had not been sufficiently developed for a complete electrical drive to be considered. However, the management being progressive, partial conversion to electric drive was considered even at that time. The plant included two multiple-story buildings used as machine and erecting shops, a forging shop, a building used for some machine operations, for dropping malleable castings and for a warehouse, a wood-working shop and warehouse, another warehouse, and a malleable and a grey iron casting foundry. There were in all five engines driving these different shops, with the necessary trans-

missions from one building to another. In a few cases, quite elaborate systems of shafting were installed to drive a single piece of machinery; such, for instance, as the elevator in the warehouse. The engines ranged from 150 to 500-h.p. It was not possible at that time to determine accurately the aggregate of power consumed in that plant, but it was estimated that a single 1500-h.p. engine would carry the entire load. In the light of later developments, this amount now seems excessive, as a number of shops have since found that the amount of loss by friction in the transmission is greater than what was estimated at that time, namely 30 per cent. The single engine could have been run condensing, as plenty of water was at hand. The several smaller engines did not pay, of course.

50 The following items would have decreased expenses, if this plant had been driven electrically:

a Lower first cost of engines.
b Lower first cost of boilers.
c Lower cost of piping.
d Lower cost of power houses.
e Lower cost of stacks.
f The omission of all transmission machinery.
g Greater economy of the engine in its steam consumption.
h Economy in oil and waste.
i Economy in repairs.
j Reduction in the number of engineers required.
k Reduction in the number of firemen required.
l Saving in the handling of coal and ashes.
m A probable more even load during the day, as the greater number of machines on a single engine has a tendency to equalize the load.

51 A number of these points are of value when a power plant is newly built, but are of no value where an established power plant is to be changed. To offset the above items the following must be considered:

a Greater first cost due to the generators.
b Greater first cost due to the wiring.
c Greater first cost due to the motors.

52 Besides, there are a great number of other factors to be considered. In this plant there were no duplicate engines, so that it would not be fair to figure in the first cost of the electrical installa-

tion of a reserve unit; though, of course, good present-day engineering would consider this an absolute necessity. It is true that where there are a number of engines, the breaking down of a single engine does not throw the entire plant out of action; but it is also true that in the plant under consideration the stoppage of a single department would soon have closed the entire plant. Considerations of this kind cannot be generalized, but must be taken up in detail in every specific case.

53 Another point to be kept in mind is, that copper wire largely takes the place of transmission machinery, and that such wire is an asset with practically no depreciation except that due to fluctuation in price (and this may be up as well as downward). On the contrary, transmission machinery should be considered as an expense, as in most cases it has no value except as scrap iron when no longer in use.

COST OF UP-KEEP

54 Still another point, and one which should have most careful consideration, is the value of the time of the plant, and the relative chances of a breakdown. In some plants the process is continuous: that is, the product goes from one machine to another without interruption, and the breakdown of a single machine would cause the stoppage of the entire plant. In such cases the breakdown should be charged with the amount of the productive capacity of the entire plant during all of the time lost. In other plants the various machines balance each other only roughly and often there is a small surplus of almost all kinds of machines in use, while some of the machinery is used only part of the time. Where these conditions prevail, the loss due to a breakdown of a single machine may be simply the cost of repairing the apparatus. In a majority of cases, neither of these two extremes is the true condition, and the engineer considering the kind of drive to be used must make some estimate of the loss due to a breakdown in any part of the installation. It should be kept in mind that the correctness of his estimate can never be established by positive proof; for, no matter which course he takes, it is impossible to say positively what would have been the result if he had pursued the other.

55 Though all of the points mentioned above affect the ultimate economy of the power installation, their relative importance changes with local conditions. For example, while the saving in the coal bill may be of the greatest importance where coal is high-priced and where

the expenses for power are a large portion of the total expenses, this saving may be a vanishing quantity where coal is cheap, and where the expenses for power form but a small fraction of the total expenses of the plant.

56 While in the example cited there was a decided saving in the number of engineers required there may still have been a loss on this score, due to the fact that in some small plants a high-grade engineer must be employed for an electrical installation, whereas a combination engineer and fireman would be good enough for the engine-driven proposition. And so on all along the line: what is a saving in one case may be a loss in another.

COST OF UNIT POWER

57 In practically all cases which have come to the notice of the writer, the cost of power per unit has gone down after conversion to electric drive, but in no case was it possible to point out in what way the saving was effected, as in addition to the substitution of electric drive for shaft transmission there were always other changes which might affect the cost of the power. Such changes were, more efficient engines, better boilers, new auxiliary devices, etc. Also in all these cases, the amount of power required after the conversion was greater than before: but this was not proof that the new installation was less effective than the old one, however, the probable cause in all these cases being that the output of the shop increased much more than the amount of power saved would have taken care of. It is almost to be regretted that high-speed steels made their entrance into the shop almost simultaneously with the electric drive. Though both are good, they have obscured each other to such an extent that it is almost impossible to trace the effects of each item separately.

CHOICE OF THE ELECTRIC SYSTEM

58 If, after considering all these points in a general way, the engineer comes to the conclusion that the electric drive will decrease expenses, then the next step will be to select the nature of the drive. The diagram in Fig. 2 shows the main points to be considered.

59 Whether a central generating station or a multiplicity of smaller plants is preferable, depends again on local conditions. Certain conditions might make a number of generating plants preferable, as for example, in a plant which consists mainly of a machine

shop requiring considerable power, with a smaller wood-working shop located at a considerable distance from the rest of the plant. In this case, the outlay for copper to supply the wood-working shop with power would be considerable; whereas, by placing an individual generating plant near the wood-working shop, the shavings might be used instead of coal.

60 Another case would be where a portion of the shop requires a great amount of power, but only for a short time each day, or perhaps at long intervals, thus necessitating a large outlay in generating machinery and copper. By separating this plant, the outlay for copper is avoided and a cheaper class of generating machinery may be used.

61 The writer has in mind a plant devoted to the making of electric generators and motors. By far the greater part of its output is in

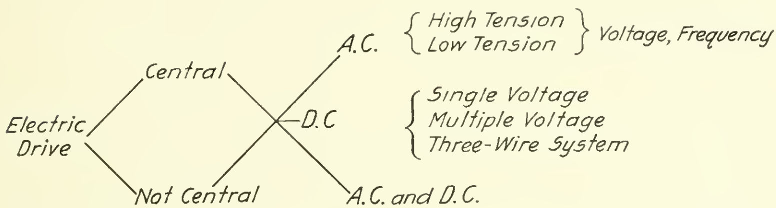


FIG. 2 SHOWING THE DIVISIONS OF ELECTRIC DRIVE

smaller units, but a certain small percentage is in larger generating units. The power required for testing these large generators exceeds in amount all the power required for the entire plant. This plant gets its current from a central station near by, but the amount of copper required for the large testing currents would be more than the cost of installation of a cheap gas engine and generator. Here again the engineer must consider conditions as he finds them and must not be governed by general principles only.

ALTERNATING OR DIRECT CURRENT

62 The question whether alternating or direct current should be used is especially difficult of solution, and there is a wide difference of opinion among engineers as to which is best. It way be that too many engineers look at this proposition only from a power standpoint, without giving due attention to the output of the plant. Commercial reasons also have figured largely in the past, the representatives of

companies manufacturing both kinds of apparatus naturally advocating the alternating variety, as by so doing they eliminated some competition. Now that more electrical companies manufacture alternating apparatus, this phase of the matter has almost entirely disappeared

63 *Alternating current.* It may be said that, all other conditions being the same, alternating current offers an advantage when the distances over which the current must be transmitted are considerable. The fact that current can be generated at high voltage diminishes the amount of copper needed for transmission, but here again the problem is not simple. Attention must be paid to the expenses incurred in step-up and step-down transformers and auxiliary apparatus; and also to the fact that money invested in copper conductors is lost only in part, while money invested in auxiliary apparatus is lost almost entirely in case of a change. There are a number of cases where the installation of alternating current would be the only practical solution, on account of the long distances and the heavy currents to be carried.

64 The advantages of alternating current, as well as its disadvantages, are well understood, and it is unnecessary to call attention to these points. It may be well, however, to point out instances where it is easy to make a choice. Given a plant covering a large area and using large amounts of current, of which only a small portion is used for variable-speed machinery, and of sufficient size to permit of the use of a separate unit for lighting current, and alternating current would be the logical solution. On the other hand, given a compact plant, using a large portion of the power for variable-speed machinery, direct-driven by motors, and of which the lighting load is small in the daytime, and it would be natural to select direct current. As a rule, however, conditions are not so simple, and it is generally very difficult to prophesy which system will give the best results. Of late the problem has been complicated by the fact that a great many machine tools may be had with single-pulley drive, to which an alternating-current or a direct-current motor is equally applicable.

65 *Alternating-current motors.* The points in favor of the alternating-current motor are then:

a High breakdown point; that is, the motor goes on with no material change in speed under very heavy overload.

b Freedom from commutator trouble. This is especially valuable where fine chips are made, or where compressed air is used in connection with the machine. It is not such

a weighty point as it used to be, as the better makes of direct-current motors are now equally free from this kind of trouble.

c Most cities are now lighted by alternating current, so that city current can be used in smaller plants, provided the machine tools are arranged for this kind of motor.

66 *Direct-current motors.* The points in favor of the direct-current motor are:

a Wider air-gap, allowing a greater amount of wear in the bearings before the motor has to be repaired.

b The possibility of power and lighting-loads on the same circuits without the poor regulation due to inductive load.

c The possibility of using variable-speed motors. This is, perhaps, the greatest argument in favor of the direct-current motor. Though it is possible to run a great many machine tools by a motor, yet one of the greatest advantages of such a drive is not available, unless the motor is of the variable-speed variety.

67 *Alternating voltage.* When a decision has been reached as to the nature of the current to be employed, the next step will be to decide as to the voltage. A high voltage is likely to be in favor if distance was a controlling factor in the decision to use alternating current: for it is this possibility of using high voltage, which makes alternating current desirable under those conditions. Where the distances are relatively small, it becomes simply a matter of computation whether low copper cost plus the expenses for transformers, etc., will give greater or less economy than high copper cost without auxiliary apparatus. In a great number of cases, current is bought from some power company, and in such cases there is no choice. In any case, however, it remains to be decided to what voltage the current shall be transformed. Few engineers nowadays adopt the 440-volt current, on account of the greater danger, and for the same reason 500-volt direct current is very little used. It should be kept in mind that alternating current is more dangerous than direct current of the same voltage.

68 *Frequency and phase.* Frequency depends on the use to be made of the alternating current. In late years a compromise has been reached, which fills practically all wants of the shop by one single frequency, namely 60 cycles.

69 Though there is still some difference of opinion, the question of

the number of phases is now fairly well settled in favor of the three-phase current. It would be difficult, however, to point out the advantage of this system over the two-phase system, or vice versa, as far as use in shops is concerned.

70 *Direct voltage.* The choice of voltage is easier when direct current is used. There was a time when the multiple voltage seemed to take a strong hold on engineers for use in machine shops, and the writer must confess that he had strong faith in the ultimate success of this system. However, the development of the variable-speed motor has made the system somewhat superfluous and it has not been installed in any new shops of late. It might be said that, for all practical purposes, the system is dead.

71 There is, however, a kind of multiple-voltage system in use which deserves even at the present day the serious consideration of the engineer. This is the three-wire system, which allows of the use of 110 and 220 volts in the same shop. The 110–volt system alone would require a large amount of copper for power purposes, while the 220–volt installation leads to some difficulties in regard to lighting. However, there are many installations where the 220–volt system is used throughout, both for power and lighting, while the number of shops where a 110–volt system is used for both purposes is very small.

72 There are a few shops using 500 volts, but the number is very small as compared with the other voltages; and it is generally possible to trace the reason for such an installation to the fact that the 500-volt current is available because used for some other purposes, as, for instance, in the case of a repair shop for a street railway system. This system is not to be recommended for a shop (though it is economical in the use of copper), for the reason that it is dangerous and where there are a large number of circuits and much metal in buildings and machinery great care must be taken to avoid grounds.

73 *Combined alternating-current direct-current systems.* There is finally the combination of alternating and direct current to be considered. This combination has its advantages, especially where it is possible to purchase current from some large power company, which as a rule delivers its product as alternating current. Transformers reduce the voltage to the proper point at the entrance to the shop, and the low-voltage alternating current can be used for all purposes except for driving variable-speed motors, and perhaps some auxiliary apparatus such as magnetic clutches, lifting magnets, etc. As the cost of installation is generally low in such a case, and the price per unit of power usually less than it could be made for, such an arrangement is so

inviting that a number of objectionable features may be overlooked. The most serious objection, perhaps, to this method of driving a shop, is that the shop has absolutely no control over the supply of current, and there is nothing to be done in the case of a breakdown but sit down and wait. This is especially serious, as power delivered in this manner is generally transmitted over a long distance which increases the chance of a break in the wires especially in bad weather.

METHODS OF APPLYING MOTORS TO MACHINE TOOLS

74 The mode of application of a motor to a machine tool, the selection of the motor, and the lines along which economical results may be expected, are fairly well defined at the present time. The following tabulation shows the present state of the art.

75 *Bench lathes:* To be driven from a countershaft, attached to the wall or bench and driven in its turn by a motor. Any kind of motor, except a series-wound or heavily compounded motor will do. The object of the motor drive is to get the machine in the best possible location without regard to the location of the line shafting. A number of these machines may be driven by a common line shaft, driven by a motor.

76 *Speed lathes:* To be driven from a countershaft, located under the lathe, or by a direct-connected motor. In the latter case, a variable-speed motor is to be preferred, if direct current is available. Motor drive is recommended when the machine is used in the assembling department as the machine may then be placed where it is most needed, and the assembling department being generally of greater height than other departments crane service would interfere with countershafts. There will be no material gain, if the machine is to be used for ordinary shop operations.

77 *Engine lathes:* Various modes of motor-driving are in use. Some makers furnish motor-driven engine lathes as standard apparatus. Some have a headstock with a limited number of speeds and depend on a variable-speed motor to fill out the speeds of the lathe. Others apply a constant-speed motor, or one with a limited amount of variation, to an all-geared headstock. In general the use of this class of machines in the shop would naturally lead to group drive. Advantages of the individual motor drive lie in the possibility of completing a job in one setting. There is no material advantage, if the machines are used for regular manufacturing operations, except where the location demands the motor drive.

78. *Heavy engine lathes, forge lathes, etc.:* To be driven by a direct-connected motor. The motor should be direct-current, as these machines are too heavy to permit a convenient all-gear drive. If no direct current is available and there is only one machine of its class in the shop, and this is used for an occasional job only, an alternating-current motor could be used, leaving a wide gap in the speeds. If these machines are used for manufacturing purposes, however, it will pay to install a small synchronous connector. The speed range in the motor does not need to exceed two to one, though a wider range is better if obtainable without complications or large expenses. The position of the motor should be low, as the vibrations in the motor-support have a decided influence on the capacity of the machine, as well as on the repair bill. The output of this class of machine may easily be increased from 20 per cent to 25 per cent by motor drive.

79 Further advantages of the motor drive are, the possibility of placing the machine in the line of the routing of heavy work, and of placing it immediately under the traveling crane. This latter object may be reached with a belt-driven machine by placing the headstock under the gallery, if the construction of the shop lends itself to this arrangement, but the same convenience as that of the motor drive cannot be obtained.

80 *Axle lathes, wheel lathes and driving wheel lathes:* It is of the greatest importance that this class of machinery should have the highest possible efficiency, and the most convenient location. These machines are mostly used in railroad repair shops, where time saved does not mean merely the saving of some wages, but each day gained means an added day in the earning capacity of the engine. It is therefore important that these machines be motor-driven whenever installed in a railroad repair shop, though this does not mean that they should not be so driven if used for manufacturing. Direct current should be used. The economy of the motor drive should not be figured in increased output, but in reduction in time required to repair an engine.

81 *Chucking lathes:* Generally speaking, there is little reason why a chucking lathe should be motor-driven. Most chucking lathes are provided with the necessary mechanism to shift speeds quickly. A few types handling large work may be motor-driven to advantage, though practically the only advantage lies in the fact that small graduations in speed can be thus obtained. Such machines therefore require a variable-speed motor.

82 *Automatic screw machines:* Small machines of this class are

generally group-driven. Large machines may be motor-driven to good advantage. The larger sizes have generally one or two speeds for one piece of work, though these speeds may be varied when the machine is reset for a new piece of work. The speed given to the machine must naturally be proportional to the largest diameter to be turned, or in other words, to the size of stock used. This will reduce the speed for some of the operations, such as drilling, and reaming, far below the economical speed. The amount of time saved by the application of the variable-speed motor may be considerable. Where the construction of the machine permits, two motors, one for feed and one for speed, would give still better results. In all cases variable-speed motors should be used.

83 *Drill presses:* The only reason why a sensitive drill should be individually motor-driven is, that it is often used in an assembling department, where height of ceiling and crane service would make a belt drive awkward or impossible. Most sensitive drills have in themselves all the speeds required for their work, so that any type of motor will be adaptable. The motor may either be directly applied to the machine or may drive a countershaft on a stand, or be placed on the floor by the side of the machine in case the machine carries its own set of cones or other variable-speed device.

84 *Drill presses:* Generally speaking, the upright drill is used for manufacturing operations and does not require frequent changes of speed. There are, however, many exceptions, for instance, where upright drills are used to do all the operations on a piece by means of a jig. In this case frequent changes of tools, and therefore of speeds, are required, and an individual motor drive, whether direct-connected to the machine, or operating on the countershaft, is of the greatest benefit. No great benefit can be derived from a constant-speed motor with this type of machine. Radial drills may be considered the same as upright drills. There is an additional reason why radial drills should be motor-driven—they are often used in the neighborhood of the assembling floor.

85 *Boring machines:* Where boring machines are specialized, performing only one operation, there is no good reason why the motor drive should be preferred to belt drives. Where, however, the machine is used for a multiplicity of operations, such as drilling, boring, reaming and facing, a motor drive is beneficial if a variable speed motor is used. The range of speed of the motor should be as wide as possible, that no gears may have to be shifted for the entire set of operations on a single hole. Especially where a boring machine is used for facing, this variable speed will be found highly economical.

86 *Grinders:* Grinders in general require so many various movements driven from countershafts that it is hardly possible to apply a single motor directly to the machine. The best that can be done is to attach the countershaft to the machine and drive the former from a motor standing on the floor or on a bracket attached to the machine. In isolated cases it would be well to have one or more motors, each controlling a single operation, attached directly to the machine.

87 *Planers:* Planers in general are not benefited by the application of a motor, as the motor only complicates the difficulties of a planer drive. However, large planers which must be placed under a crane give better results when motor-driven on account of the facility of handling the work. Another possible advantage when using a variable-speed motor and controlling the speed of the motor at the end of the stroke, is that much higher return speeds can be obtained in connection with any desired cutting speed.

88 *Shapers, slotters etc.:* What is true of planers is also true of these classes of machines. Local conditions may make it advisable to drive them individually by motor, but generally speaking, there is no great benefit with this drive.

89 *Milling machines:* The larger sizes of knee-and-column type machines, if motor-driven, will give the best results if the motor is of the variable-speed type, especially where these machines are used for gang work. This is due to the fact that the speed of the mills is dependent on the largest cutter in the gang, while the feed is dependent on the smallest cutter, not counting the limitations due to the nature of the work. It is therefore important that the speed should be as close to the permissible limit as possible. When applied to this type of milling machine the motor should be as low down as possible, as vibrations in the machine have a marked effect on the quality of the finish.

90 *Planer-type milling machines:* In practically all cases this type of machine should be motor-driven in order that they may be located under a crane. It is not so very material, however, whether the motor is of the constant-speed or variable-speed type.

91 *Punches, bending rolls, shears, etc.:* This class of machinery, used largely for boiler, bridge, structural iron and ship-building work, is generally placed in high shops and under cranes, and in locations and directions most convenient for the routing of the work. The shops in which they are placed are generally large and contain a relatively small amount of machinery, so that the amount of transmission gearing required is large in proportion to the amount of

machinery. It is for this reason advisable in almost all cases to drive this class of machinery by an electric motor, which, of course, does not need to be of the variable-speed type.

92 It was not the intention to go into detail on the application of the motor to the machine tool, and the above should be considered as merely an enumeration of some of the important points on the most constantly used machines. It is in no way a treatise of motor drive applied to machine tools.

THE BUCYRUS LOCOMOTIVE PILE DRIVER

By Walter Ferris, South Milwaukee, Wis.
Member of the Society

The machine described in this paper is of some engineering interest as the most substantial and complete railway pile driver yet produced. Its special claims to consideration as a new development in mechanical engineering, however, lie in the unusual arrangement and strength of the self-propelling mechanism, and in the self-contained hydraulic turntable, whereby the entire machine, including trucks, is quickly lifted clear of the rails and turned end for end. The propelling engines, mounted on the car body and delivering more than 250 h.p., are connected to the axles of ordinary bogie trucks without interfering with the movements of the trucks in turning curves, passing over frogs, and the like.

2 The machine was designed to meet the requirement of the Atchison, Topeka & Santa Fe Railway system, for a pile driver capable of climbing any grade on their line and hauling its own cars of piles, tools, etc. The self-propelling pile drivers built hitherto are capable of moving themselves for short distances while at work, but from lack of sufficient steam capacity as well as engine power must have a locomotive in constant attendance. The services of this locomotive are usually charged against the bridge department of a railway at the rate of from $20 to $30 per day. After having used several of the ordinary self-propelling machines, A. F. Robinson, bridge engineer of the Santa Fe system, prepared specifications calling for a pile driver of much higher propelling power. This resulted in the designing by the Bucyrus Company of the machine herein described, which has been in active service on the Santa Fe lines since January 1909.

3 The general appearance of the machine is shown in the illustrations. Fig. 1 shows the machine with leaders folded in shipping position. Fig. 2 shows the leaders up ready for driving with the swinging frame turned across the track, and also shows how the coun-

All papers are subject to revision.

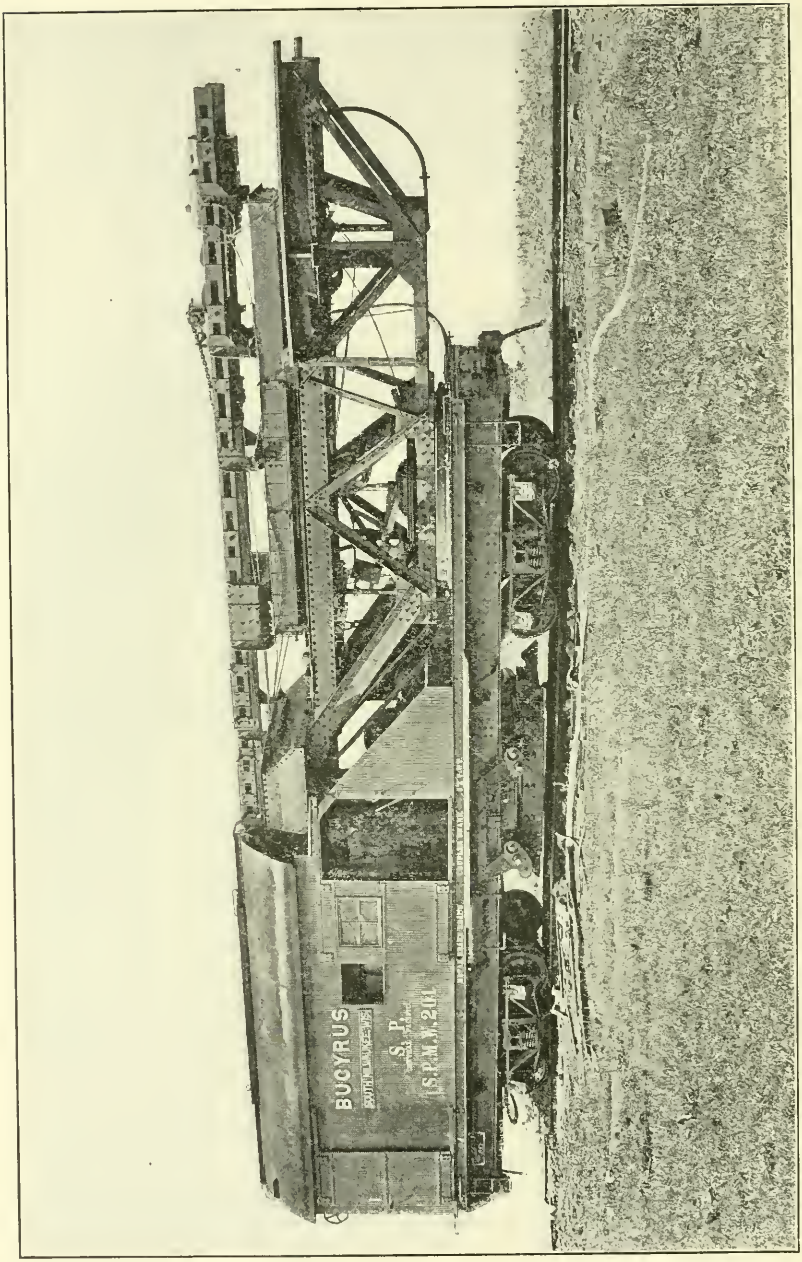


Fig. 1 The Bucyrus Locomotive Pile Driver with Leaders Folded in Shipping Position

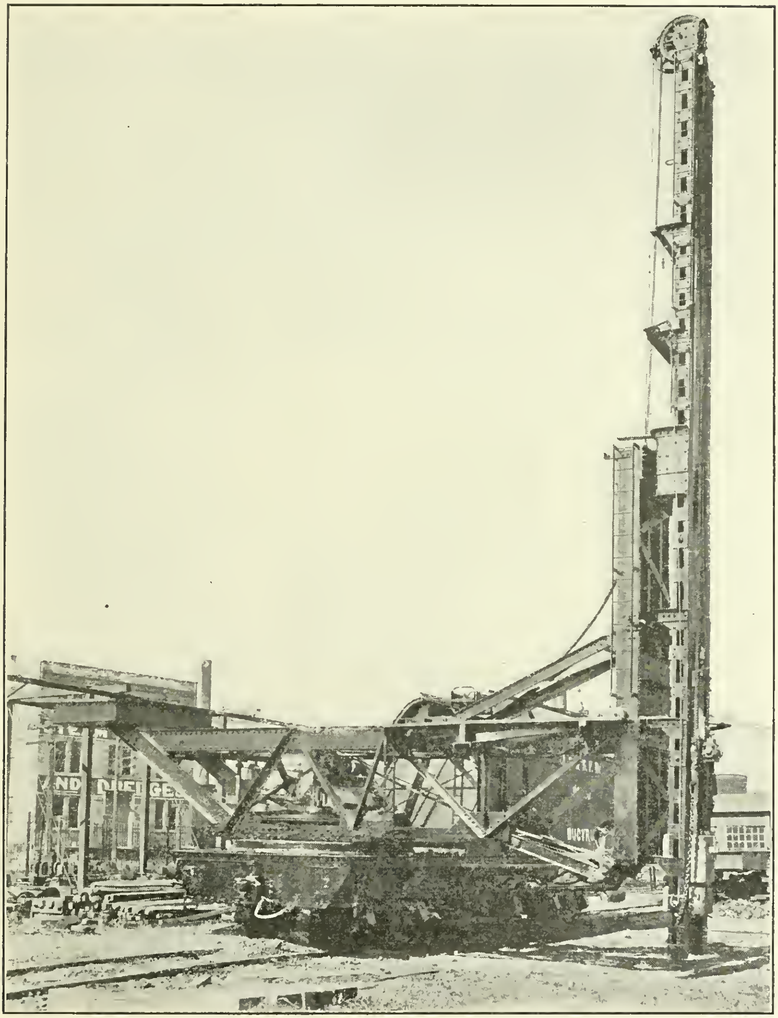


FIG. 2 THE LEADERS IN POSITION FOR DRIVING WITH THE SWINGING FRAME ACROSS THE TRACK

terweight on the opposite side of the swinging frame balances the weight of the leaders, keeping the machine always in a stable condition. In this position a pile can be driven 19 ft. from the center of the track.

4 Fig. 4 shows the machine standing on its hydraulic turntable with all wheels in the air. In this position and without any blocking the pile was picked up, put in place in the leaders and driven at a distance of 32 ft. from the center of the track. It was not desirable to drive this pile all the way in and the leaders were therefore backed down to clear the partially driven pile. The principal use of the hydraulic turntable, which will be described later on, is to turn the machine end for end when there is no railway turntable or "Y" available.

5 Fig. 3 shows the general arrangement of machinery. The car is 40 ft. long, built entirely of structural steel and steel castings. On the front end is mounted the swinging frame, shown in Figs. 1, 2 and 4, consisting of a pair of parallel trusses supporting the leaders at one end and a counterweight at the other end with the necessary parts for raising and lowering the leaders and swinging the entire frame to the right or left at right angles to the car body. This frame is swung by a large worm wheel, which also serves to raise and lower the leaders.

6 The latter operations are accomplished by means of the long worm-wheel hub projecting upward through the center pintle upon which the swinging frame revolves, a double-grooved sheave or drum being keyed to the upper end of the worm-wheel hub. This drum is provided with a clutch by which it can be engaged with the main base plate of the revolving frame. When this clutch engages with the swinging frame the latter moves with the worm wheel. When the clutch is out of engagement, however, and a brake is applied between the car body and the swinging frame, the revolution of the worm wheel does not carry the swinging frame with it, but merely turns the drum, which is keyed to the worm wheel.

7 The ropes leading from the drum to either end of the revolving frame are so arranged as to raise or lower the leaders. The details of the worm wheel, drum, clutch, etc., are clearly shown in Fig. 5. This figure also shows a large circular base plate on the car, for supporting the weight of the revolving frame. The latter is provided with four conical rollers which rest upon the finished upper surface of the base plate.

8 From Fig. 3 it may be seen that the leaders are mounted on a

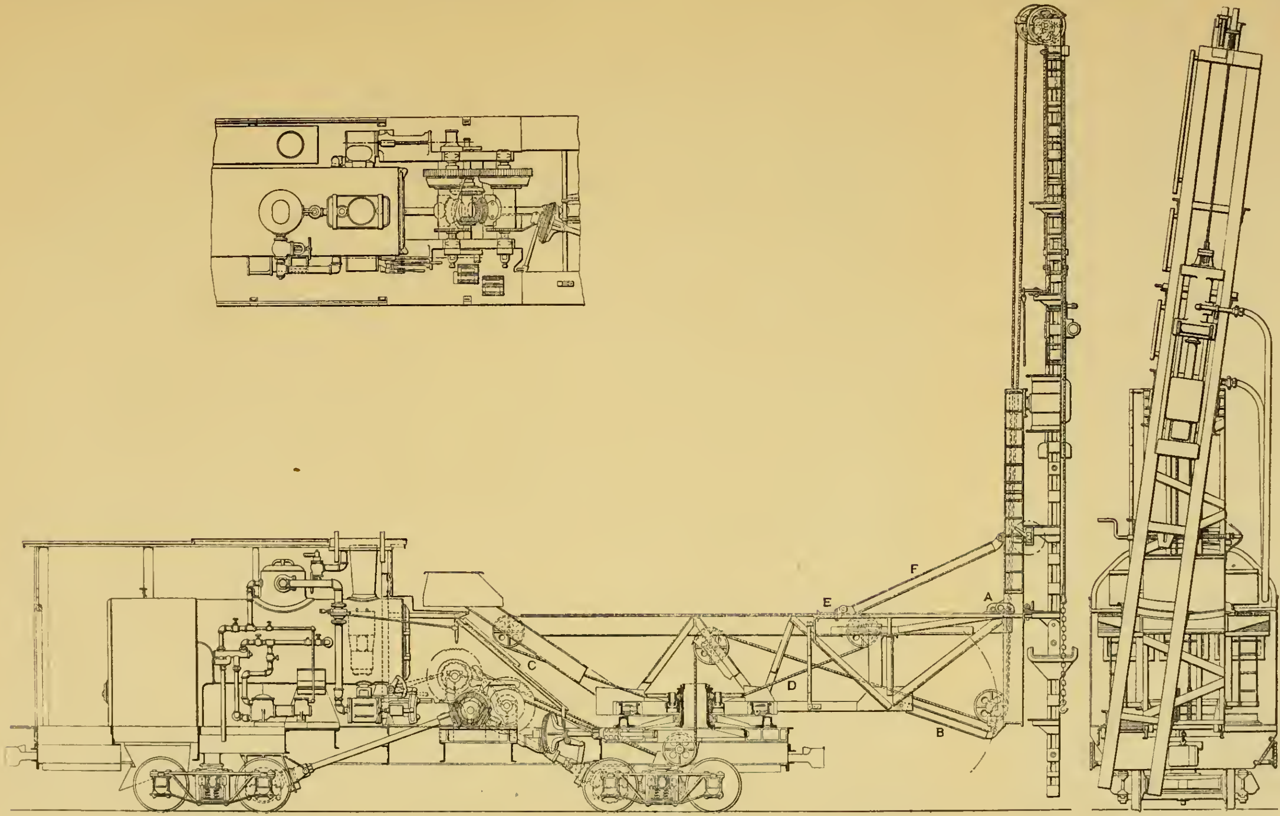


FIG. 3 SIDE AND FRONT ELEVATIONS AND PARTIAL PLAN OF BUCYRUS LOCOMOTIVE PILE DRIVER

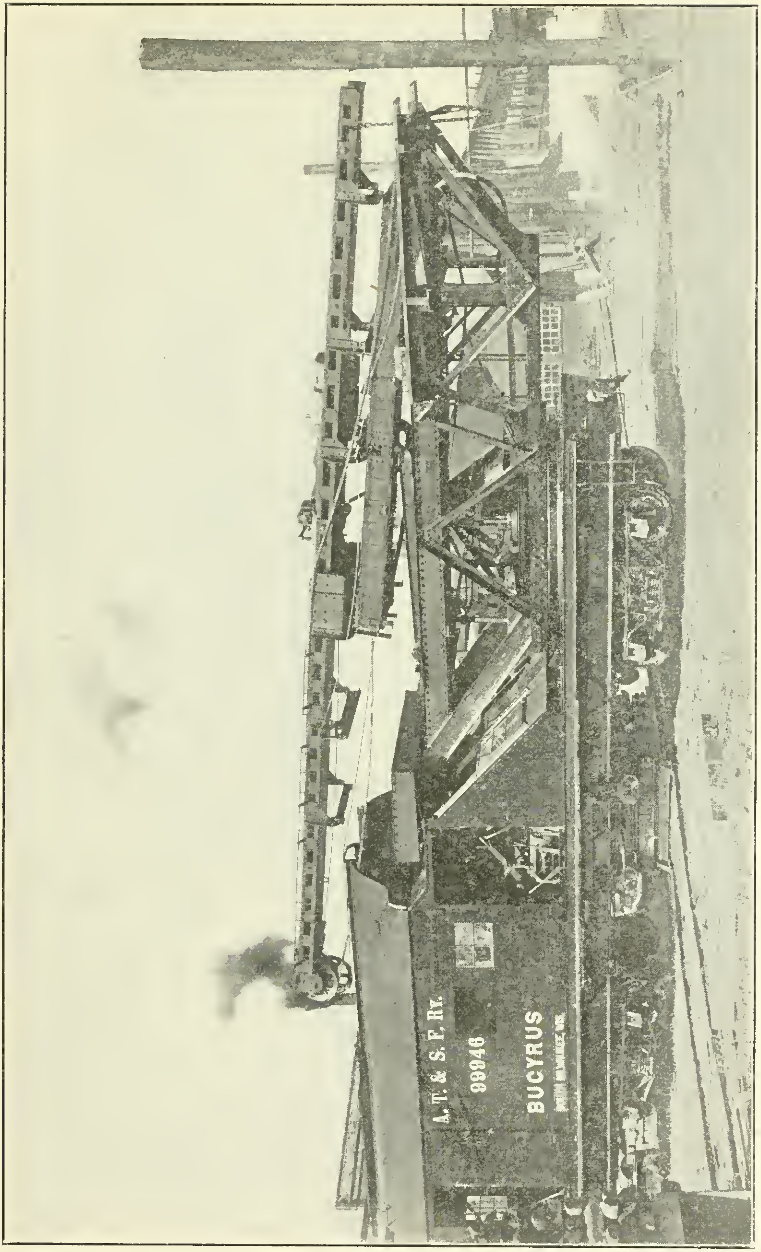
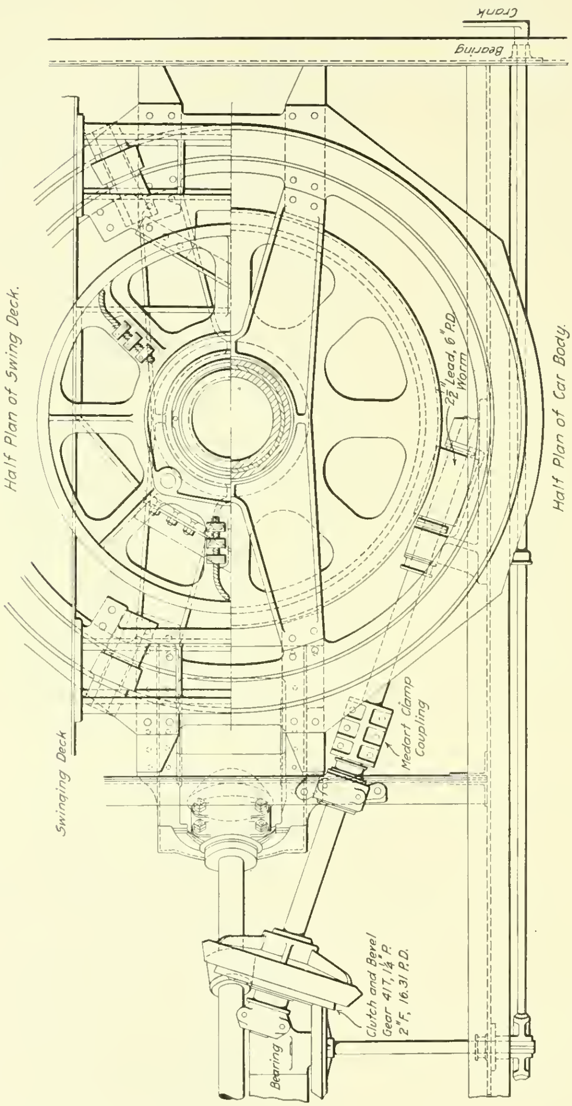


Fig. 4 The Pile Driver Standing on the Hydraulic Turntable with Both Trucks off the Ground


Crank
Bearing
Half Plan of Swing Deck.
Half Plan of Car Body.
2½" Lead, 6" P.D. Worm
Swinging Deck
Medart Clamp Coupling
Clutch and Bevel Gear 41 T, 1¼" P. 2" F, 16.31 P.D.
Bearing

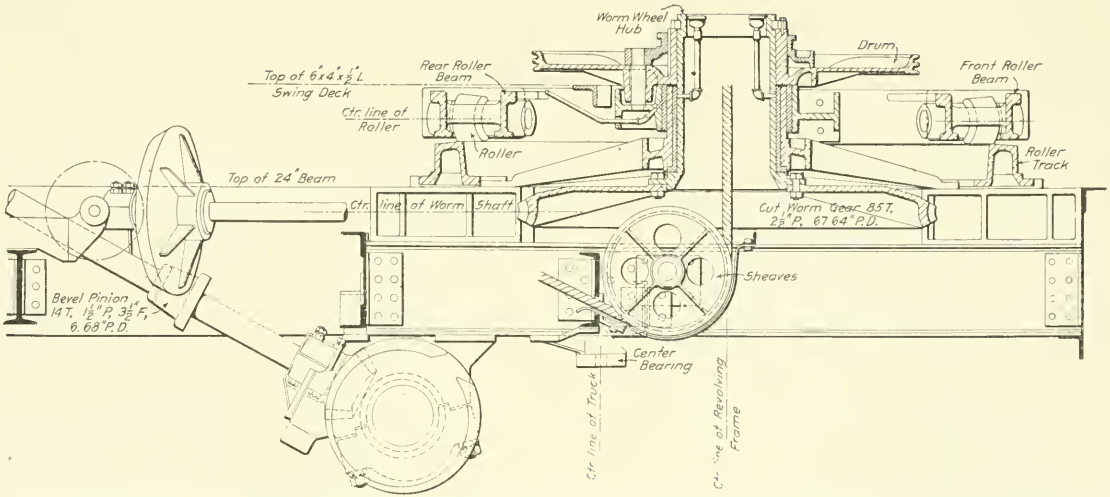


Fig. 5 Plan and Sectional Elevation of Swinging and Propelling Mechanism of the Locomotive Pile Driver

leader-raising frame by means of a pivot near the center of the leaders. A screw and nut device takes hold of the leaders some distance below the pivot and with this they can be inclined either to right or left so as to drive batter piles. The arrangement for raising and lowering the leaders acts directly upon the raising frame, which is carried by two rolling trucks *A* which roll on the top of the upper chords of the swinging frame, while the radius arm *B* takes hold of the lower end of the raising frame, causing it to move in the arc of a circle as indicated. The ropes *C* and *D* over the drum pass around suitable idler sheaves and are anchored to the sliding crosshead *E* forming a closed circuit. From this crosshead the raising arms *F* take hold of the raising frame, transmitting the movement of the crosshead to the latter. The hammer-hoist rope, pile-hoist rope and steam pipe (the last-named is not shown) run up from the car body to the swinging frame through the large hollow hub of the swinging worm wheel. The steam pipe is on the center and the ropes are so close on either side that they work equally well with the leaders in any position with regard to the car body.

9 The main engines are 11 in. by 12 in., with double cylinders and Stephenson link motion. From the crank shaft the two drums for the pile-hoist and hammer-hoist lines are geared in the usual manner with cone friction clutches. The engines, however, are much more powerful than would be required for these drums. The propelling gearing consists of two inclined shafts leading from the crank shaft of the engine to the rear axle of the forward truck and the forward axle of the rear truck. From Fig. 3 it will be seen that each of these shafts carries on its upper end two bevel gears, while the crank shaft carries a sliding sleeve with a small bevel gear on one end and a large one on the other end, the two meshing respectively with the two pairs on the inclined driving shafts. By sliding the sleeve to one end or the other a fast or slow propelling ratio is obtained.

10 With the fast gear, on level or moderate grades and with moderate loads, the machine can readily be driven at 25 miles per hour and has been driven at 30 miles per hour. With the slow gear the engines are powerful enough to slip the two driving axles and thus obtain all the tractive force that can be had with about 80,000 lb. weight on drivers. The machine can thus be used effectively as a switching engine and will readily haul its own weight with considerable additional load over grades of 1½ per cent or more. The acceptance-test of the first machine built was a run of 32 miles up a grade averaging 75 ft. to the mile, with a maximum of 97 ft. to the mile.

11 The lower ends of the inclined propelling shafts shown in Fig. 3 are provided with bevel pinions. These pinions mesh with bevel gears cast in one piece with large sleeves, as shown in Fig. 6. These sleeves surround the driving axles, a cored hole through the middle of the sleeves 10 in. in diameter providing about 2 in. clearance around the axles. The sleeves are supported by brackets rigidly attached to the car body with babbitted bearings. All this gearing is fastened to the car body only and remains in line without regard to the swivelling of the trucks.

12 The connection by which the driving torque is communicated from the propelling sleeves to the axles is also shown in Fig. 6. It consists of a modified type of universal joint so arranged that there is nothing to interfere with the axle passing through the middle. The propelling sleeve carries at one end a large flange with lugs supporting two pins *G*; these pins engaging with two bronze bushed lugs *H* formed on the inner side of the toggle casting *i*. On its outer side it carries another pair of lugs *J* on an axis at right angles to the axis of the pins *G* and these lugs *J* are connected to a U-shaped driving yoke *K*. The open end of this yoke is again pin-connected to a bracket *L* which is keyed to the axle.

13 Both pins, *G* and *M*, are made much longer than the lugs which engage them, to permit end play due to the displacements of the axle, as shown on the plan view in Fig. 6. As these two pin axes are at right angles to each other their combined slip will take care of any movement of translation, while the combined revolution of the parts around the pins *G*, *M* and *N* provides for any possible twisting. The wearing parts involved are six steel pins and six bronze bushings, all of the same size, and all parts are so made that the wearing surfaces can be replaced without taking the truck from under the machine. The pins are made hollow and are packed for continuous lubrication.

14 The method of detaching the driving gears when it is desirable to ship the pile driver in a freight train is slightly indicated in Fig. 3, at the rear axle of the front truck, where an operating lever is shown taking hold of the bearing which supports the bevel pinion at the lower end of the forward driving shaft. This bearing and the pinion are mounted in a sliding support, which enables the pinion to be drawn out of mesh with the bevel gear, permitting the propelling sleeves and gears shown in Fig. 6 to revolve freely with no gears in mesh. The same arrangement is provided on the rear truck.

15 In order to provide the necessary steam capacity for these propelling requirements, the boiler required is nearly three times the

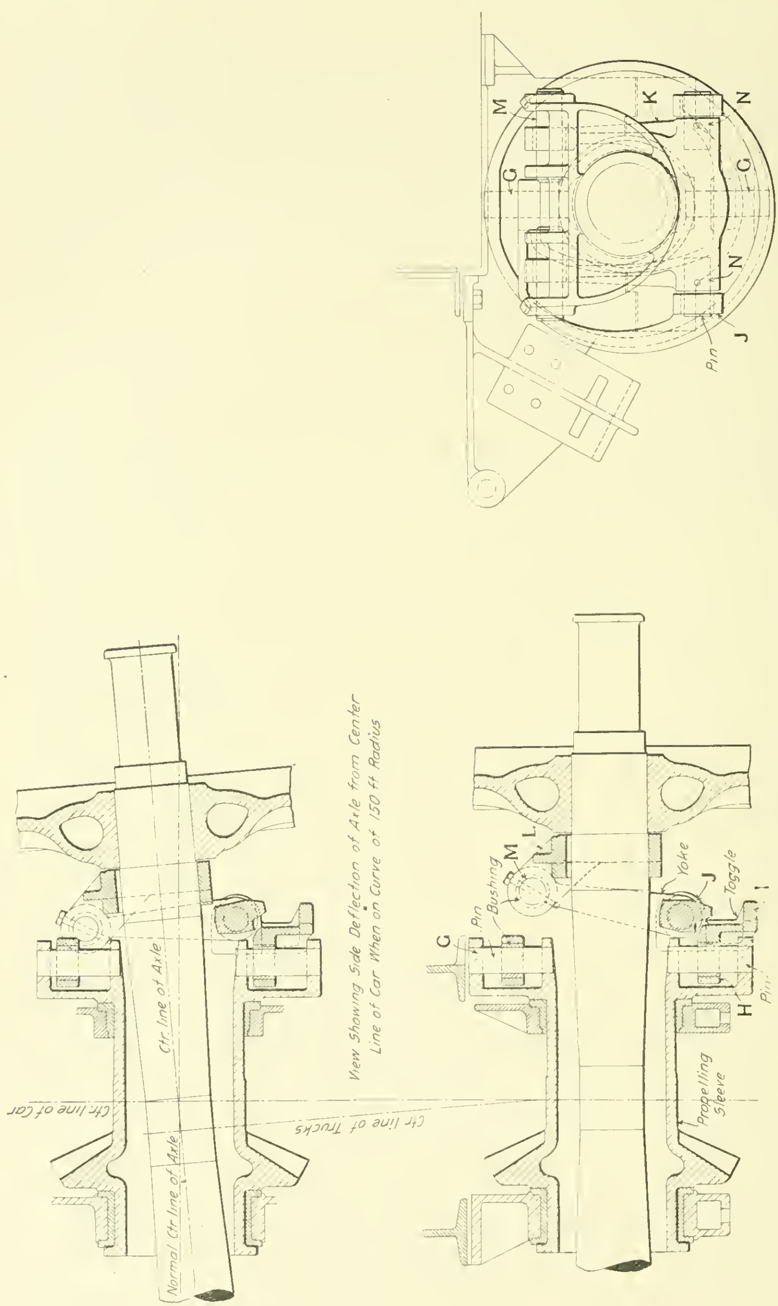


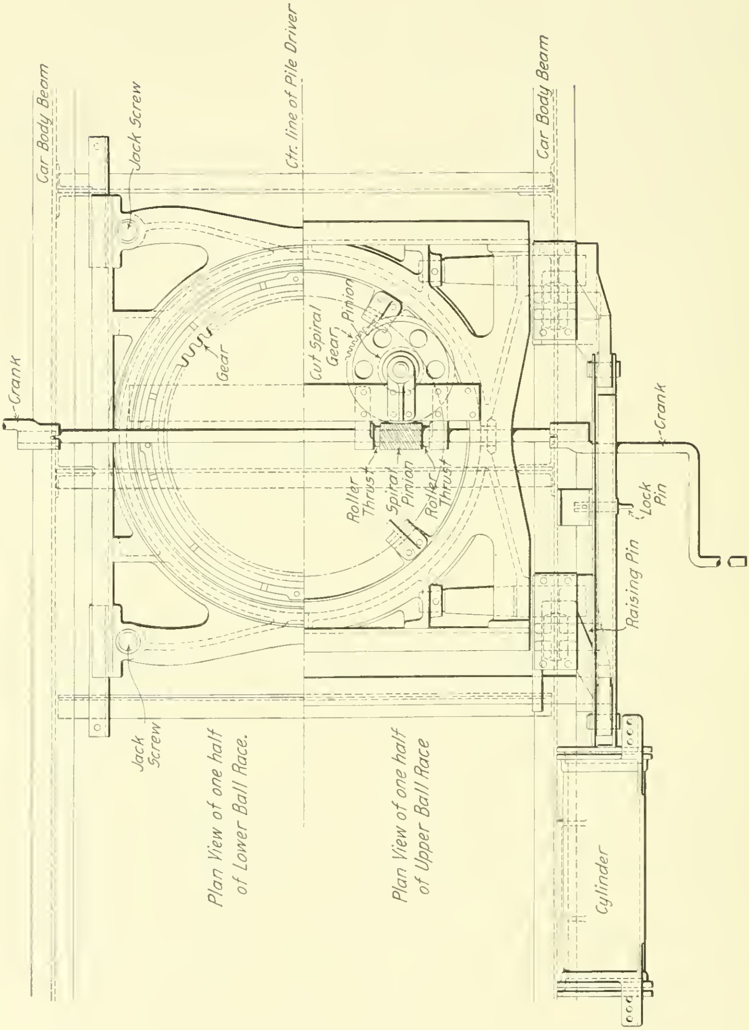
Fig. 6 Sections and End View of Toggle Joint

size of those ordinarily furnished for pile drivers. The boiler is of the locomotive type, 54 in. in diameter, 15 ft. 9 in. long, having about 800 sq. ft. of heating surface and designed for 175 lb. pressure. This pressure is required only for steam economy on propelling runs, as the engines are so large that all the ordinary movements of the machine can be made with 100 lb. pressure.

16 One of the striking features of the machine is the hydraulic turntable, which is shown in action in Fig. 4, and in shipping position in Fig. 1. It is frequently very important that a pile driver should be able to turn end for end or else to work at either end indifferently. The latter plan requires that the boiler and pile-driving machinery shall all be mounted upon a swinging deck, which can be turned through a full circle and reach either end of the car. This plan has been thoroughly tried and is satisfactory as far as pile driving is concerned, but makes it impossible to get a sufficiently powerful and reliable propelling gear between the engines and the trucks. In the new machine, therefore, the pile-driving apparatus is mounted on the car body where it can work at one end only, thus obtaining the powerful propelling drive already described. To reverse the machine the hydraulic lifting jack shown in Fig. 7 is attached underneath the car and under the center of gravity of the entire structure.

17 This jack consists of two ball-race castings having races about 5 ft. in diameter provided with 2-in. steel balls. The upper ball race is carried upon a set of four bell cranks or levers *O*, two on each side of the car, the bell cranks being pivoted upon brackets *P* attached to the main car beams. The upper ends of each pair of bell cranks are connected by a parallel rod, while the rear bell cranks on the two sides of the car are connected across by a heavy shaft *Q*. This arrangement compels all four bell cranks to act in unison, and when they are operated by the hydraulic cylinders the four pins from which the upper ball race is suspended move up and down the same distance, maintaining the turntable at all times parallel to the car, even though the center of gravity may be quite a distance away from the center of the turntable.

18 The system of bell cranks is operated by a pair of hydraulic cylinders 12 in. in diameter, having about 28 in. stroke. One cylinder is located on each side of the car. The cylinders have trunk pistons with sufficient area between the outside of the trunk and the bore of the cylinder to provide lifting force enough to raise the turntable away from the track and put it in shipping position. While lifting


Car Body Beam
Jack Screw
Ctr. line of Pile Driver
Car Body Beam
Crank
Gear
Cut Spiral Gear
Pinion
Roller Thrust
Spiral Pinion
Roller Thrust
Crank
Lock Pin
Raising Pin
Jack Screw
Plan View of one half of Lower Ball Race.
Plan View of one half of Upper Ball Race
Cylinder

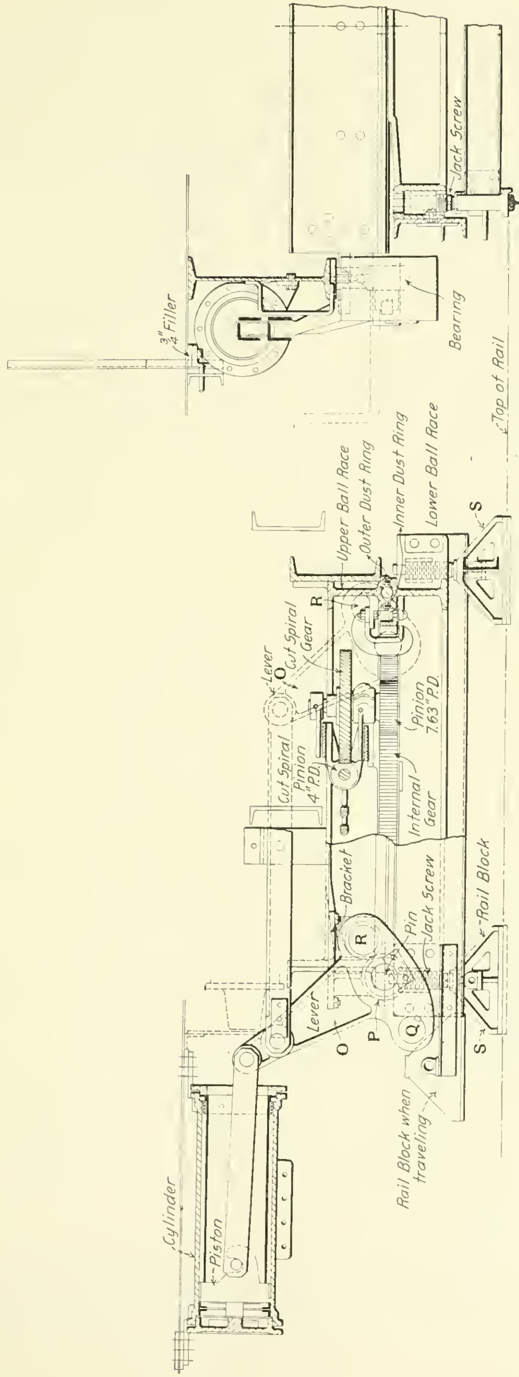


FIG. 7 PLAN AND SIDE AND FRONT ELEVATION OF HYDRAULIC TURNTABLE OF LOCOMOTIVE PILE DRIVER

the car the pressure acts upon the full area of the 12-in. piston. The working pressure of about 200 lb. per sq. in. is provided by the boiler feed pump.

19 The lower ball race, which is suspended from the upper ball race by suitable clips, is also provided with a set of chair castings which rest on the rails and can readily be placed under the four jack screws, which are located in the four corners of the lower ball race. The lower ball race also carries a circular rack, while the upper ball race has a transverse shaft with a crank on each end and a double gear reduction to a swinging pinion which meshes with the rack on the lower ball race.

20 When the machine is to be turned it is necessary only to put the chair castings *s* under the jack screws and run the latter down until they touch the chairs. The entire car is then raised by pumping water into the hydraulic cylinders and turned end for end by hand, two men working on each crank. In a high wind three men may be required on each crank. The entire turning operation occupies from 10 to 15 minutes.

21 An important incidental advantage of the turntable has already been touched upon in Par. 4. Fig. 2 and Fig. 4 show its use to enable the driver to reach a pile at a long distance from the center of the track. In this way, should occasion arise, any point within 32 ft. of the track may be reached and the pile driven.

22 The tests made since the first machine was put in operation indicate that it will fully come up to expectations. The first machine was built with slow gear only, having a maximum speed of 15 miles per hour. The results of its test on grades have already been mentioned. It has since been in constant use on the western divisions of the Santa Fe and on heavy grades. The fast propelling gear herein described has now been added and two machines thus equipped have been built and shipped. On one of these, built for the Canadian Pacific Railway, the following speed test was made. The machine hauled an ordinary passenger car from South Milwaukee to Racine and return, a distance of 12.6 miles each way. The run to Racine was made in 31 min., an average speed of 24.4 miles per hour, two miles being made at a speed of 30 miles per hour. The return run was made in 37 min., making an average speed of 20.5 miles per hour.

23 The shipping weight of the machine without the turntable, as shown in Fig. 3, is about 147,000 lb.; with the turntable, as shown in Figs. 1, 2 and 4, about 160,000 lb. It is equipped with either a No.

2 steam hammer or a 3500-lb. drop hammer, or both. The leaders are so made that either hammer can be used without change. The reach for driving piles is 18 ft. ahead of the center of the forward wheel, or 19 ft. on each side, as already mentioned; while with the turntable, 32 ft. on either side can be reached. The leaders are 40 ft. long. The construction is entirely of metal, except the house.

ACCESSIONS TO THE LIBRARY

BOOKS

American Railway Association. Statement of Committee on Relations between Railroads on Freight Car Balance and Performance. April 1909 and September 15, 1909. (Statistical Bulletin No. 54, 55–A). *Chicago, 1909.* Gift.

Architectural Institute of Canada. *Proceedings,* First General Annual Assembly, September 28–October 1, 1908. Quarterly Bulletin Vol. 11. Nos. 2–3. April-July 1909. *Montreal, 1909.* Gift of Institute.

Brief History of Cements. By I. C. Johnson. *Kansas City, 1909.* Gift.

Brooklyn Engineers' Club. *Proceedings.* 1898, 1902–1905. *Brooklyn, N. Y., 1899, 1903–1906.* Gift of Club.

Colloid Matter of Clay and its Measurement. (Bulletin No. 388, U. S. Geological Survey.) By H. E. Ashley. *Washington, Govt., 1909.* Gift.

Digest of Data Collected before the Year 1908 Relating to the Sanitary Condition of New York Harbor. Prepared by the Metropolitan Sewerage Commission. *New York, 1909.* Gift of H. deB. Parsons.

Effect of Oxygen in Coal. (Bulletin No. 382, U. S. Geological Survey.) By David White. *Washington, Govt., 1909.* Gift.

Engineers' Club of Toronto. Constitution and By-Laws, List of Members, etc., 1909. *Toronto, 1909.* Gift.

"Growth" of Cast Irons after Repeated Heatings. By H. F. Rugan and H. C. H. Carpenter. 1909. Gift of H. F. Rugan.

Library of Congress. Want List of Periodicals, new ed., 1909. Want List of Publications of Societies, new ed., 1909. *Washington, Govt., 1909.* Gift.

Merchants' Association of New York. Report of Committee on Water Supply Against Construction of more Reservoirs in the Croton Valley. *May 3, 1909.*

Notes on Explosive Mine Gases and Dusts. (Bulletin No. 383, U. S. Geological Survey.) By R. T. Chamberlin. *Washington, Govt., 1909.* Gift.

Selden Patent Broadly Sustained. 1909. Gift of Association of Licensed Automobile Manufacturers.

Structural Materials in Parts of Oregon and Washington. (Bulletin No. 387, U. S. Geological Survey.) By N. H. Darton. *Washington, Govt., 1909.* Gift.

Travelers' Railway Guide, Eastern Section. October 1909. *New York, 1909.* Gift.

University of the United States. 1896, 1902. (54th Congress, 1st Session. Senate. Report Nos. 429, 945.) *Washington, Govt. 1896, 1902.* Gift.

Western Canada Railway Club. *Proceedings.* Vol. 2. No. 1. *Winnipeg, 1909.* Gift.

Western Railway Club. *Proceedings.* Vol. 21. *Chicago, 1909.* Exchange.

Reprints from Third Annual Convention of the Illuminating Engineering Society, September 27–29, 1909

Gift of Calvin W. Rice

Allowable Amplitudes and Frequencies of Voltage Fluctuations in Incandescent Lamps. By H. E. Ives.

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Tests of a Moore Tube. By C. H. Sharp and P. S. Millar.

Tests of Moore Tube Lighting Installations, New York Post Office. By E. P. Hyde and J. E. Woodwell.

Work of Dr. Carl Auer von Welsbach in the Field of Artificial Illuminants. By G. S. Barrows.

TRADE CATALOGUES

Alexander Milburn Co., *Baltimore, Md.* The Milburn Light. 32 pp.

Allis-Chalmers Co., *Milwaukee, Wis.* Folders and list of bulletins of pumping engine, flour mill, saw mill, electrical, steam engine and mining and crushing machinery depts. 1700 pp.

Handy Index Co., *New York.* Handy Index f r architects, engineers, builders, and contractors, October 1909. 64 pp.

Joseph T. Ryerson & Son, *Chicago, Ill.* Stock list of iron, steel, boiler, and structural iron workers' supplies. October 1909. 144 pp.

Underfeed Stoker Co. of America, *Chicago, Ill.* Publicity magazine, September 1909. 16 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society, and these are on file, with the names of other good men not members of the Society who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

079 Chief engineer in electrical department. Must have had experience in both direct-current and alternating-current design; must be capable of directing the work on both large and small apparatus, and have had actual manufacturing experience.

MEN AVAILABLE

317 Construction engineer, eleven years experience building construction of every kind; design, erection, installation of machinery and equipment, etc.; permanent position desired, to take entire charge of such work for manufacturing or engineering concern. Best references.

318 Junior, Lehigh graduate, four years experience in steel mills and one year on road as salesman. Desires commercial position, New York City preferred.

319 Superintendent desires position. Technical graduate. Extensive practical experience in manufacturing machine shop and iron foundry as executive and organizer. Qualified for position of trust and responsibility.

320 Member, graduate mechanical engineer with eighteen years experience, desires position in the East, with manufacturing corporation seeking to reduce cost of power operation or cost of output by the design of improved methods.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

BAILEY, H. Morrell (Junior, 1909), Engrg. Dept., Carnegie Steel Co., and *for mail*, Duquesne, Allegheny Co., Pa.

CAMPBELL, Jeremiah (Associate, 1896), 38 Kilby St., Boston, Mass.

CASE, Theo. Newton (1891; 1896), Klamath Falls, Ore.

CHURCH, Elihu C. (Junior, 1908), 4 E. 130th St., New York, N. Y.

COON, Thurlow E. (Junior, 1908), Mgr., Ball Eng. Co., 1809 Ford Bldg., Detroit, Mich.

DEAN, Arthur M. (Junior, 1907), Matheson Motor Car Co., Wilkes-Barre, Pa.

DE WOLFE, Edwd. Chas. (1899; 1906), Member of Russell-De Wolfe Co., 355 Dearborn St., and 586 Bryant Ave., Chicago, Ill.

ELDRED, Byron E. (1899; 1903), Pres. Commercial Research Co., 149 Broadway, New York, and *for mail*, Tuckahoe, N. Y.

ENNIS, J. B. (1909), Designing and Estimating Engr., Am. Loco. Co., 30 Church St., New York, N. Y., and *for mail*, 615 E. 24th St., Paterson, N. J.

FLANDERS, Ralph E. (Associate, 1908), Assoc. Editor, Machinery, New York, N. Y., and *for mail*, 18 Evergreen Pl., E. Orange, N. J.

FRY, Lawford H. (1905), Tech. Rep. in Europe of Baldwin Loco. Wks., 64, Rue de la Victoire, Paris, France.

GEORGE, J. Rowley (1899), Ch. Engr., Morgan Constr. Co., 21 Lincoln St., and *for mail*, 6 Bowdoin St., Worcester, Mass.

GIELE, Walter S. (Junior, 1908), 3 Hamilton Pl., New Brighton, S. I., N. Y.

GORE, Warren W. (1908), Charge Experimental Dept., Fairbanks-Morse Mfg. Co., and *for mail*, 950 Park Ave., Beloit, Wis.

HIGGINS, George F. (1886; 1906), 41 Mt. Vernon St., Melrose, Mass.

KIRCHHOFF, Charles (1882), 422 West End Ave., New York, N. Y.

NILES, Francis H. (Associate, 1907), 5437 Cornell Ave., Chicago, Ill.

PINNER, Seymour W. (Junior, 1909), Instr., Univ. of Mich., and *for mail*, 724 S. Ingalls St., Ann Arbor, Mich.

POPE, Harold L. (Junior, 1905), Engr., Matheson Motor Car Co., Wilkes-Barre, Pa.

RICHARDS, William A. (Junior, 1903), Univ. H. S., Univ. of Chicago, Chicago, Ill.

RIGGS, John D. (1892; 1907), 162 N. Pine Ave., Chicago, Ill.

ROSING, Wm. H. V. (1896), Mech. Engr., Mo. Pac. Ry. Co., and *for mail*, Hotel Berlin, St. Louis, Mo.

SETHMAN, George H. (Junior, 1899), Mech. and Elec. Engr., 125 E. 11th Ave., Denver, Colo.

SEWELL, J. G. Clifton (Junior, 1892), United Engrg. and Fdy. Co., Farmers Bank Bldg., Pittsburg, and *for mail*, 15 Hawthorne Ave., Crafton, Pa.

SHEPERDSON, John Wm. (Associate, 1908), Steam Engr., Cambria Steel Co., and *for mail*, 522 Second Ave., Johnstown, Pa.

SMITH, Edward S. (Junior, 1909), Box 172, University, Va.

SMITH, Jesse M. (1883), Manager, 1891–1894; V.P., 1894–1896, 1899–1901; Pres., 1908–1909; Life Member; Mech. and Elec. Engr. and Expt. in Pat. Causes, Rm. M-14, 220 Broadway, and *for mail*, 120 Riverside Drive, New York, N. Y.

SMITH, William E. (Junior, 1908), Babcock & Wilcox Co., and *for mail*, 316 E. Park Ave., Barberton, O.

THRELFALL, Wm. V. (1902), Rm. 601, Hitchcock Bldg., Springfield, Mass.

WAITE, Edward B. (Associate, 1902), Head of Instr. Dept., Am. Sch. of Correspondence, 58th St. and Drexel Ave., Chicago, Ill.

WHITING, S. B. (1880), Manager, 1880–1882; V.P., 1882–1883; 11 Ware St., Cambridge, Mass.

YOUNG, Gilbert A. (1906), Park Chambers, Magazine and Lake Sts., Cambridge, Mass.

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SHORKEY, Edward Louis (Affiliate, 1909), 73 North St., Bethlehem, Pa.

SMITH, Bronson H. (Affiliate, 1908), Asst. Engr., Westinghouse, Church, Kerr & Co., New York, and *for mail*, 257 E. 23d St., Brooklyn, N. Y.

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REARDON, Michael F. (Affiliate, 1909), Salesman, Genl. Elec. Co., 30 Church St., New York, N. Y.

SCHWEHR, George A. (Affiliate, 1909), Secy., Ohio Motor Co., Sandusky, O.

STUDENT SECTION

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BOLGIANO, J. R. (Student, 1909), Towson, Md.

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PARMELY, J. C. (Student, 1909), 1106 W. Univ. Ave., Urbana, Ill.

QUICK, R. L. (Student, 1909), 414 Darrow Ave., Plainfield, N. J.

RICHARDSON, L., Jr. (Student, 1909), 118 Linn St., Ithaca, N. Y.

VANDER VEER, J. H. (Student, 1909), 147 Pacific St, Brooklyn, N. Y.

WHEDBEE, Edgar (Student, 1909), Box 1176, Cascadilla Bldg., Ithaca, N. Y.

COMING MEETINGS

November and December

Secretaries or members of societies whose meetings are of interest to engineers are invited to send in their notices for publication in this department. Such notices should be in the editor's hands by the 18th of the month preceding the meeting.

ALABAMA LIGHT AND TRACTION ASSOCIATION
: November 15, 16, annual convention, Birmingham. Secy., Lloyd Lyon, 158 Government St., Mobile.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
: December 27, Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN CIVIC ASSOCIATION
: November 15–19, Cincinnati, O. Secy., Richard B. Watrous, Harrisburg, Pa.

AMERICAN FEDERATION OF TEACHERS OF MATHEMATICS
: December 28, 29, annual meeting, Baltimore, Md. Secy., C. R. Mann, University of Chicago.

AMERICAN INSTITUTE OF ARCHITECTS
: December 14–16, annual convention, Washington, D. C. Secy., Glenn Brown, Octagon Bldg.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
: December 8–10, annual meeting, Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
: November 12, 33 W. 39th St., N. Y., 8 p.m. Paper: The Electric System of the Great Northern Railway Co. at Cascade Tunnel, C. T. Hutchinson, Mem.-Am.Soc.M.E.

AMERICAN MATHEMATICAL SOCIETY
: November 27, University of Missouri, Columbia, Mo., Southwestern Section. Secy., O. D. Kellogg, 411 Hitt St.

AMERICAN PHYSICAL SOCIETY
: November 27, University of Illinois, Urbana, Ill. Secy., Ernest Merritt, Ithaca, N. Y.

AMERICAN RAILWAY ASSOCIATION
: November 17, annual meeting, Chicago, Ill. Secy., W. F. Allen, 24 Park Pl., New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
: November 9, New York; Novemb r 13, St. Louis, Mo.; November 17, Boston, Mass.; December 7–10, annual meeting, 29 W. 39th St., New York. Secy., Calvin W. Rice.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS
November 9–11, annual meeting, Little Rock, Ark. Secy., A. Prescott Folwell, 239 W. 39th St., New York.

AMERICAN SOCIETY OF SWEDISH ENGINEERS
November 20, 271 Hicks St., Brooklyn, N. Y. Paper: Magnetic Separation of Iron Ores, N. V. Hansell. Secy., E. Hammerstrom.

APPALACHIAN ENGINEERING ASSOCIATION
November 5, 6, Washington, D. C. Papers by Dr. T. L. Watson, R. H. Edmonds, D. C. Weller, Prof. R. L. Morris, E. V. N. Heermance, Mr. Fernstrom. Secy., H. M. Payne, Morgantown, W. Va.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS
December 14, 15, annual meeting, New York. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

ASSOCIATION OF TRANSPORTATION AND CAR ACCOUNTING OFFICERS
December 14, 15, Chattanooga, Tenn. Secy., G. P. Conard, 24 Park Pl., New York.

CENTRAL ELECTRIC RAILWAY ASSOCIATION
November 18, Claypool Hotel, Indianapolis, Ind. Secy., A. L. Neereamer

CENTRAL RAILWAY CLUB
November 12, Hotel Iroquois, Buffalo, N. Y., 8 p.m. Paper: Application of Electricity to the Movement of Freight, G. H. Condict. Secy., H. D. Vought.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
November 16, December 21, Prince George Hotel, Toronto. Papers: Gas Engines, their Origin and Commercial Use, D. M. Henderson; Gas Manufacture, C. G. Herring. Secy., C. J. Worth, Union Sta.

COLORADO SCIENTIFIC SOCIETY
December 18, annual meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

EMPIRE STATE GAS AND ELECTRIC ASSOCIATION
November 17, 18, 29 W. 39th St., New York. Secy., C. H. B. Chapin.

ENGINEERS CLUB OF ST. LOUIS
December 1, annual convention, 3817 Olive St. Secy., A. S. Langdorf.

FRANKLIN INSTITUTE
November 4, Section meeting, Philadelphia, Pa. Paper: The Open-Hearth Process, Prof. Bradley Stoughton.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS
November 16, annual meeting, Washington, D. C. Secy., M. S. Decker, Albany, N. Y.

NATIONAL COMMERCIAL GAS ASSOCIATION
December 12, 14, annual convention, Madison Square Garden, New York. Secy., L. S. Bigelow, Light Publishing Co., Willimantic, Conn.

NATIONAL GAS AND GASOLENE ENGINE ASSOCIATION
November 30, December 1, 2, LaSalle Hotel, Chicago, Ill. Secy., Albert Stritmatter, Cincinnati, O.

NATIONAL MUNICIPAL LEAGUE
November 15–19, Cincinnati, O. Secy., C. R. Woodruff, 121 S. Broad St., Philadelphia, Pa.

NATIONAL SOCIETY FOR PROMOTION OF INDUSTRIAL EDUCATION
December 1–3, annual convention, Milwaukee, Wis. Secy., J. C. Monaghan, 20 W. 44th St., New York.

NEW YORK RAILROAD CLUB
November 19, annual meeting, 29 W. 39th St., Secy., H. D. Vought, 95 Liberty St.

OHIO SOCIETY MECHANICAL ELECTRICAL AND STEAM ENGINEERS
November 19, 20, main annual meeting, Lima, O. Secy., David Gaehr, Schofield Bldg., Cleveland.

RICHMOND RAILROAD CLUB
November 8, annual meeting; December 13: Paper, Block Signals, Chas. Stephens. Secy., F. O. Robinson.

ROCHESTER ENGINEERING SOCIETY
December 10, annual meeting. Secy., John F. Skinner, 54 City Hall.

SHORT LINE RAILROAD ASSOCIATION
December 14, annual meeting, New York. Secy., J. N. Drake, 60 Wall St.

SOCIETY OF ENGINEERS OF EASTERN NEW YORK
November 10, Albany, N. Y. Paper on Gas Power, G. A. Orrok, Mem.Am.-Soc.M.E. Secy., W. R. Davis.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
November 18–19, annual meeting, 29 W. 39th St., New York, Secy., W. J. Baxter.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB
November 18, annual meeting, Candler Bldg., Atlanta, Ga. Papers on Oil Lamps, Front-End Arrangements, Draft-Rigging. Secy., A. J. Merrill, 218 Prudential Bldg.

WASHINGTON SOCIETY OF ENGINEERS
November 24, anniversary celebration. Secy., Paul Bausch.

WESTERN SOCIETY OF ENGINEERS
November 3, 20, December 1, 1735 Monadnock Blk., Chicago, Ill. Papers: Loss of Heat through Furnace Walls, W. T. Ray, Henry Kresinger; The Panama Railroad, Ralph Budd; Compressed Air in Contact Work, M. W. Briseler; River and Harbor Improvements at Chicago and the Calumet, T. H. Rees.

MEETINGS TO BE HELD IN THE ENGINEERING BUILDING

Date	Society	Secretary	Time
November			
3	Wireless Institute	S. L. Williams	7.30
4	Blue Room Engineering Society	W. D. Sprague	8.00
5	Explorers' Club	H. C. Walsh	8.30
6	Amer. Soc. Hungarian Engrs. and Archts.	Z. deNemeth	8.30
9	The American Society Mech. Engineers	Calvin W. Rice	8.00
11	Illuminating Engineering Society	P. S. Millar	8.00
12	American Institute Electrical Engineers	R. W. Pope	8.00
16	New York Telephone Society	T. H. Lawrence	8.00
17–18	Empire State Gas and Electric Asso.	C. H. B. Chapin	All day
18–19	Naval Architects and Marine Engineers	W. H. Baxter	All day

Date November	Society	Secretary	Time
19	New York Railroad Club	H. D. Vought	8.15
24	Municipal Engineers of City of New York	C. D. Pollock	8.15
December			
1	Wireless Institute	S. L. Williams	7.30
2	Blue Room Engineering Society	W. D. Sprague	8.00
4	Amer. Soc. Hungarian Engrs. and Archts.	Z. DeNemeth	8.30
7–10	The American Society Mech. Engineers	Calvin W. Rice	
9	Illuminating Engineering Society	P. S. Millar	8.00
10	American Institute of Electrical Engineers	R. W. Pope	8.00
17	New York Railroad Club	H. D. Vought	8.15
21	New York Telephone Society	T. H. Lawrence	8.00
22	Municipal Engineers of City of N. Y.	C. D. Pollock	8.15

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State Agri. College of Oregon, Corvallis, Ore.	March 9	Thos. M. Gardner	J. J. Karstetter	S. H. Graf
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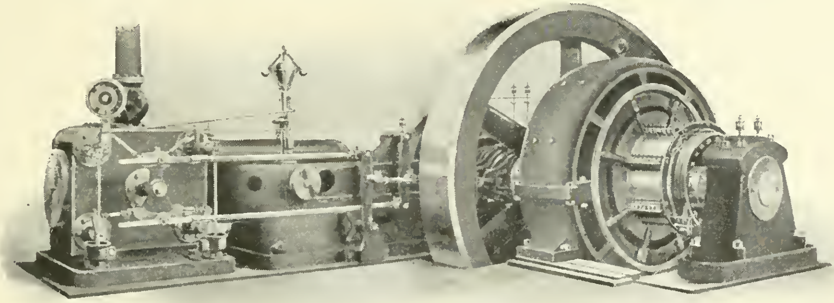

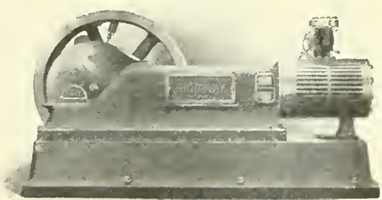

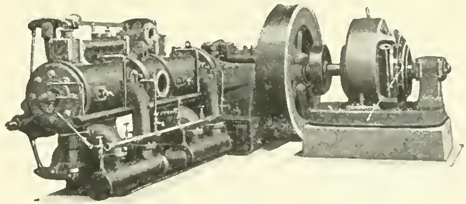

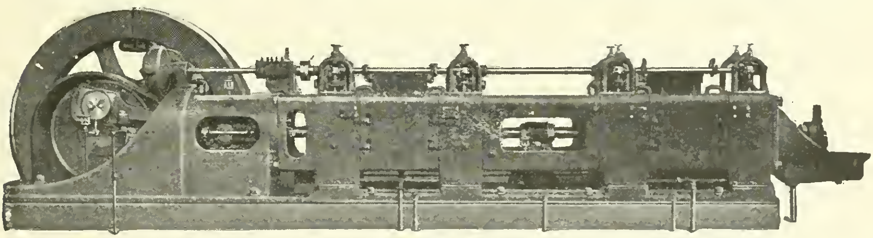

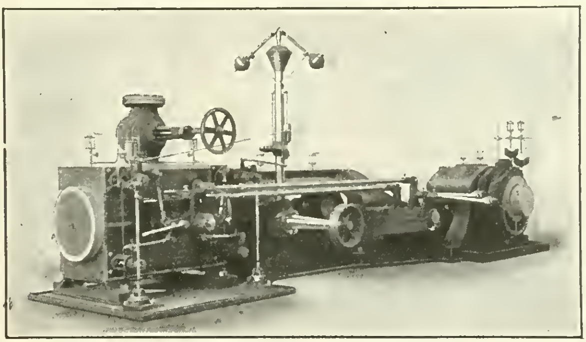

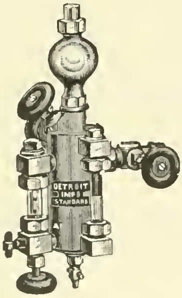

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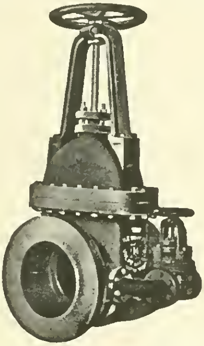

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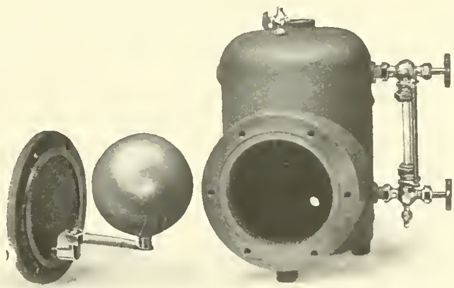

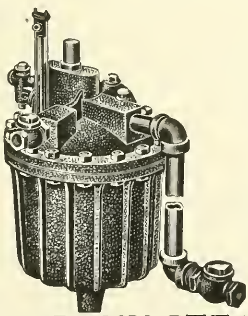

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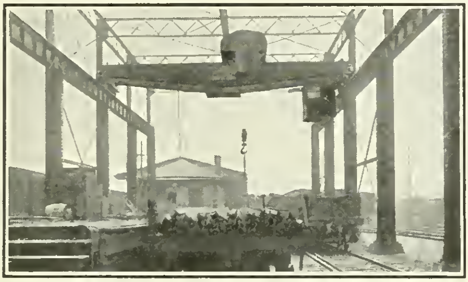

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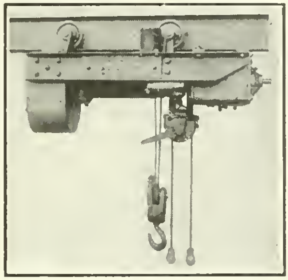

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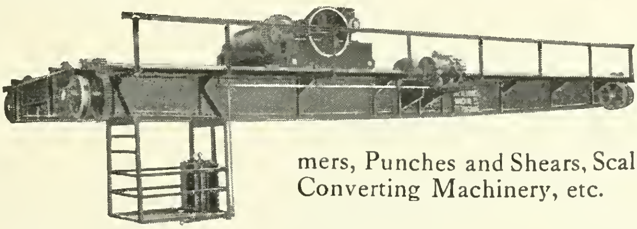

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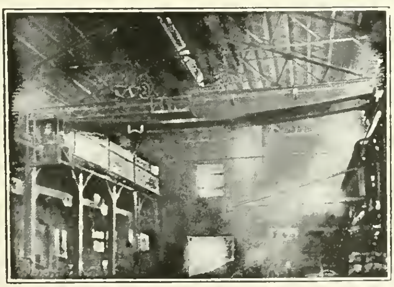

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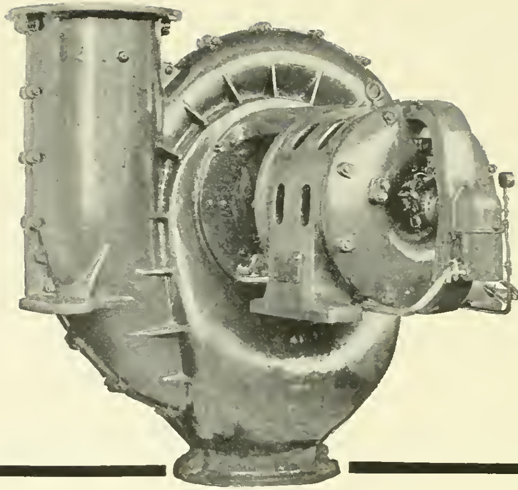

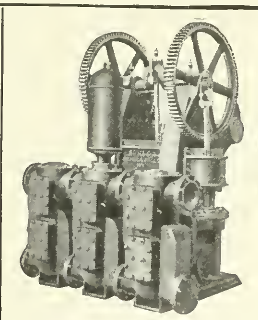

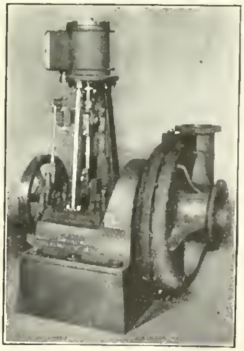

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ELECTRICAL APPARATUS

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PAPERS FROM TRANSACTIONS OF A. S. M. E.

No. 827. Standard Method of Conducting Steam Boiler Trials, price \$.50; No. 828. Discussion on No. 827, price \$.20; No. 973. Standard Method of Testing Engines, price \$.50; No. 974. Discussion on No. 973, price \$.40.

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THE

JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

MID-NOVEMBER 1909

MEETINGS OF THE SOCIETY: ST. LOUIS, NOVEMBER 13; BOSTON, NOVEMBER 17; ANNUAL MEETING, NEW YORK, DECEMBER 7-10

MID-NOVEMBER 1909 VOL. 31 No. 11

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OF

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The Journal is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.

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THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 MID-NOVEMBER 1909 NUMBER 11

THE ANNUAL MEETING

The thirtieth annual meeting of the Society will be held in the Engineering Societies Building, 29 West 39th St., New York, December 7 to 10.

The Meetings Committee, Mr. Willis E. Hall, Chairman, having entire charge of the professional program and the arrangement of professional sessions, has provided a list of strong papers upon varied subjects; a preliminary program, subject to revision, being published in the following pages.

For the first time at an annual convention of the Society the entire social entertainment will be in charge of the members resident in and about New York, under the immediate direction of a local committee appointed by them, of which Mr. William D. Hoxie is chairman. For Wednesday afternoon of the convention an excursion is planned which the members and guests will be asked to attend in a body, and during the balance of the time there will be opportunities for smaller parties to visit places of interest. Full announcement of the entertainment features, which form so important a part of these meetings, will be made in the next number of The Journal.

It is not possible for the Secretary to undertake to reserve hotel accommodations for visiting members. They are recommended to communicate directly with the hotel at which they wish to stop.

PRELIMINARY PROGRAM FOR THE ANNUAL MEETING[1]

OPENING SESSION

Tuesday, December 7, 8.15 p.m., Main Auditorium

The President's Address
Report of tellers of election of officers
Introduction of new president

The reading of the President's address will be followed by a social gathering at which ladies will be especially welcome.

BUSINESS MEETING

Wednesday, December 8, 9.30 a.m. Main Auditorium

Annual business meeting. Reports of the Council, tellers of election of membership, standing and special committees and Gas Power Section. Amendments to the Constitution. New business may be presented at this session.

Luncheon will be served to members and guests at 1. p.m. on the fifth floor of the building. The afternoon of this day will be left free for members and guests to go on an excursion planned by the Excursion Committee.

PROFESSIONAL SESSION

Wednesday, 8.15 p.m., Main Auditorium

(To be assigned)

PROFESSIONAL SESSIONS

Thursday, December 9, 9.30 a.m. Main Auditorium

MEASUREMENT OF THE FLOW OF FLUIDS

TESTS ON A VENTURI METER FOR BOILER FEED by Chas. M. Allen
THE PITOT TUBE AS A STEAM METER, Geo. F. Gebhardt

[1] Subject to Revision.

All professional meetings of the Society will be called to order at the time specified on the program.

Efficiency Tests of Steam Nozzles, F. H. Sibley and T. S. Kemble

An Electric Gas Meter, C. C. Thomas

Luncheon will be served to members and guests on the fifth floor of the building at 1 p.m.

Thursday, 2 p.m., Main Auditorium

STEAM ENGINEERING

Tan Bark as a Boiler Fuel, David M. Myers

Cooling Towers for Steam and Gas Power Plants, J. R. Bibbins

Some Studies in Rolling Mill Engines, W. P. Caine

An Experience with Leaky Vertical Fire Tube Boilers, F. W. Dean

The Best Form of Longitudinal Joint for Boilers, F. W. Dean

Thursday, 2 p.m., Auditorium, 6th floor

SIMULTANEOUS SESSION

Gas Power Section

Business meeting and election of officers.

Testing Suction Gas Producers With A Koerting Ejector, C. M. Garland, A. P. Kratz

(Subjects of other papers to be announced)

RECEPTION

Thursday, 9 p.m.

This will be the social event of the meeting in which members and guests and especially the ladies are invited to participate. Cards of admission will be required, which can be obtained from the Local Committee at the registration desk.

PROFESSIONAL SESSION

Friday, December10, 9.30 a.m., 6th floor

The Bucyrus Locomotive Pile Driver, Walter Ferris

Line-Shaft Efficiency, Mechanical and Economic, Henry Hess

Pump Valves and Valve Areas, A. F. Nagle

A Report on Cast-Iron Test Bars, A. F. Nagle

RAILROAD TRANSPORTATION NOTICE

For members and guests attending the Annual Meeting in New York, December 7–10, 1909, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 3 and 9 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained, Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival, present your certificate to S. Edgar Whitaker at headquarters, with 25 cents for validation. A certificate cannot be validated after December 10.

d An agent of the Trunk Line Association will validate certificates December 8, 9 and 10. No refund will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for certificate, and to turn it in at headquarters. Even though you may not use it this will help others to secure the reduced rate.

f If certificate is validated, a return ticket to destination can be purchased, up to December 14, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlotteville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

New England Passenger Association, except via Bangor and Aroostook R. R., Rutland R. R., N. Y. O. & W. R. R., Eastern Steamship Co. and Metropolitan Steamship Co.

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri; north of a line through Kansas, Jefferson City and St. Louis, Illinois; north of a line from Chicago through Peoria to Keokuk.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

IMPROVEMENTS IN THE ROOMS OF THE SOCIETY

The headquarters of the Society have recently been made more attractive than ever before by appropriate additions to the furnishings and by rearrangement of the rooms. When the Society entered the new headquarters nearly three years ago, provisional furnishings were purchased comprising only what was essential to carrying on the business of the Society with no attempt at decorative features. The members will be pleased to find the rooms as homelike as can be desired and convenient in every way as a rendezvous for the members and their friends.

During the past year the Council authorized these improvements and the work is being carried out under the direction of the House Committee, consisting of Henry S. Loud, *Chairman*, W. C. Dickerman, Bernard V. Swenson, Francis Blossom and Edward Van Winkle. The original plans of the rooms provided for a large reception hall, with an attractive alcove, which visitors enter from the elevators. In common with the other floors of the building this hall was open to the stairway connecting the several floors. A partition cutting off this stairway and another partition separating the offices at the rear, has converted this hall into a reception room which is not only pleasing in appearance but thoroughly comfortable.

Wide sliding doors connect the three main rooms, known as the Council Room, the Library and the Secretary's office, which, usually remaining open, give the effect of one spacious room.

The floors of the Reception Room, the Council Room and the Library have been covered with handsome rugs and the walls tinted in harmony with them. Comfortable upholstered furniture has been placed in the Reception Room and cushions on the seats in the alcove. Improvements now being carried out will include portieres between the rooms, draperies at the windows and comfortable divans and chairs in the Council Room and Library, and shelves in the Library for books which will furnish a pleasant half hour while waiting for a friend.

In undertaking this work the House Committee has endeavored so to complete the furnishing as to make the already beautiful rooms of the Society so homelike as to form a constant reminder to the mem-

bership of the pleasant rooms at the former home of the Society at 12 West 31st Street, and to make a place which members will use freely for their own convenience, and in meeting other members or friends for social or business engagements. In addition to the three large rooms referred to a small room is especially reserved for members of the Society, where they may have quiet to attend to their correspondence or to hold conferences in private.

Fine art photographs of the past-presidents have been placed on the walls of the Library and by order of the Council a similar photograph of each succeeding president will be added as he retires from office.

An improvement which will be greatly appreciated by the membership is the placing of a name-plate on each of the portraits, paintings and other historical objects in the rooms of the Society. A very complete catalogue of all of these objects of historical interest has been carefully prepared after long and painstaking research by Edward Van Winkle of the House Committee. The members will find much of interest in this work which will be open to them in the Library.

It is hoped that all members of the Society when they are in New York will make a special effort to come to the rooms and make use of the comforts and conveniences which have been provided for them.

GENERAL NOTES

BROOKLYN POLYTECHNIC STUDENT SECTION, AM.SOC.M.E.

At the annual meeting of the Brooklyn Polytechnic Student Section affiliated with The American Society of Mechanical Engineers, held October 16, Chairman J. M. Russell, presiding, the following officers were elected: John S. Kerins, chairman; Russell C. Brown, vice-chairman; Percy Gianella, secretary; Wilbur N. Sar Vant, treasurer. The committee on admissions reported a membership of 107. The address of the evening was on Industrial Engineering, its Province, Limitations, Ideals, by Charles Buxton Going.

PURDUE MECHANICAL ENGINEERING SOCIETY

Meetings of Purdue Mechanical Engineering Society, of Purdue University, Lafayette, Ind., affiliated with The American Society of Mechanical Engineers, were held upon October 6 and 20, with addresses by Prof. J. D. Hoffman, on The Manufacture of Paper from Wood Pulp; and Mr. Fenstermaker of the American Engineering Supply Co. of Indianapolis, on The Application of the Vacuum System of Heating to Old Factory Plants.

AMERICAN STREET RAILWAY ASSOCIATION

The annual meeting of the American Street Railway Association took place this year at Denver, Colo., October 4 to 8. Excursion trains were run from points East and West, and the attendance was over 2500 members and guests. The sessions were held in a large auditorium built for the purpose, with rooms for the various sectional meetings and for an exhibit of machinery, equipment and supplies. The convention was opened after an address of welcome by Wm. G. Evans, president of the Denver City Tramway Company, by the presidential address of James F. Shaw, which rehearsed street railway conditions for the year. Organization from the Standpoint of Smaller Companies was the title of an important paper by Ernest Gonzenbach, president of the Cheboygan Company. With the exception of the secretary, Bernard V. Swenson, Mem.Am.Soc.M.E., resigned, the

retiring officers were re-elected. A secretary will be appointed by the president.

The auxiliary organizations of the association, which held executive sessions simultaneously with the parent society, were the Traffic and Transportation Association, the Accountants' Association, the Claim Agents' Association, and the American Street and Interurban Railway Engineering Association. At the sessions of the latter, the annual address was made by Paul Winsor. Officers of the American Street and Interurban Railway Engineering Association were elected as follows: president, F. H. Lincoln, Philadelphia, Pa., vice-presidents, W. J. Harvie, Syracuse, N. Y., E. O. Ackerman, Columbus, O., J. S. Doyle, New York, J. W. Corning, Boston, Mass.

AMERICAN ASSOCIATION OF RAILROAD SUPERINTENDENTS

The Central Association of Railroad Officers at their twenty-second annual meeting, held at Cincinnati, O., September 22 and 23, adopted a new constitution, which it is felt will broaden the scope of the organization. The name is changed to the American Association of Railroad Superintendents. The organization now has divisions at the following points: Cincinnati, O.; Indianapolis, Ind.; Columbus, O.; Toledo, O.; Peoria, Ill.; St. Louis, Mo.; Kansas City, Mo.; Louisville, Ky.; Detroit, Mich.; Denver, Colo.; Omaha, Neb.; Memphis, Tenn.

The following officers were elected: president, J. A. Somerville; vice-presidents, Brent Arnold, S. M. Russell; secretary-treasurer, O. G. Fetter.

NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION

The eighth annual convention of the National Machine Tool Builders' Association was held in New York October 12 and 13, with headquarters at the Hotel Astor. The attendance at the opening session was larger than ever before. The annual presidential address was made at this session by Fred. L. Eberhardt, of Newark, N. J., Mem.Am.Soc.M.E. There was discussion on The Standardization of Electric Motors used in Connection with Machine Tool Drive; and on The Creation of Machinists, introduced by a paper. Papers on Industrial Education were also submitted by Frederick A. Geier, of the Cincinnati Milling Machine Company, Mem.Am.Soc.M.E., and M. A. Coolidge, who dealt with the Fitchburg plan. A lecture entitled The Perils of Peace, or A Safer America, was delivered by J. P. H. Perry, of New York.

The election of officers resulted as follows: president, F. A. Geier, Mem.Am.Soc.M.E.; vice-presidents, F. L. Eberhardt, Mem.Am.Soc. M.E., the retiring president, P. E. Montanus, Springfield, O., the retiring secretary; secretary, C. Hildreth, Worcester, Mass.; treasurer, G. W. Fifield, Lowell, Mass. The Spring meeting of the association will be held at Rochester, N. Y.

Many members of the association were entertained at a theater party given by *The American Machinist;* and on the annual outing of *Machinery*, to Fort Hancock and the Sandy Hook Proving Grounds.

RAILWAY SIGNAL ASSOCIATION

The annual meeting of the Railway Signal Association was held at the Seelbach Hotel, Louisville, Ky., October 12 to 14. President L. R. Clausen in his opening address spoke of the vigorous growth of the association since its formation in Chicago in 1895, from 6 members to more than 1100. The discussion was on Signaling Practice. The election of officers, by letter-ballot, was announced: president, H. S. Balliet, of New York; vice-president, C. C. Anthony, of Philadelphia, Pa.; secretary, C. C. Rosenberg, Bethlehem, Pa.; Eastern and Western representatives on the executive committee, C. J. Kelloway and B. H. Mann, respectively.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

At the Chicago meeting of the American Society of Refrigerating Engineers, October 18 and 19, papers were presented by J. C. Wm. Greth, Mem.Am.Soc. M.E., on Water Purification for Ice and Refrigerating Plants; Walter L. Hill, Assoc.Am.Soc.M.E., on Cold Storage Temperatures; Dr. Charles E. Lucke, Mem.Am.Soc.M.E., on Wet vs. Dry Compression; Fred. W. Wolf, Jr., Mem.Am.Soc.M.E., on Autogenous Welding. There will be a meeting in New York December 6.

ILLUMINATING ENGINEERING SOCIETY OF GREAT BRITAIN

The first of the technical sessions of the Illuminating Engineering Society recently organized in London will be held in November. The honorary secretary of the society is Leon Gaster, editor of *The Illuminating Engineer*, of London, and Prof. S. P. Thompson has consented to become the first president. Influential support has been received from many distinguished authorities on matters of illumination in Great Britain, on the Continent and in America, and a representative council has been formed.

PERSONALS OF THE MEMBERSHIP AM. SOC. M.E.

Robert W. Angus gave an address at the October 14 meeting of the Engineers' Club of Toronto, in which he described some of the better European science laboratories and large factories.

Chas. Edgar Ard has assumed the duties of manager of Christopher, Ard & Co., Starkville, Miss. He was formerly professor of physics and electrical engineering, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.

Earle J. Banta has become identified with the Cincinnati Equipment Company, Cincinnati, O. Mr. Banta was until recently mechanical engineer, Isthmian Canal Commission, Culebera, Canal Zone, C. A.

John H. Barr, second vice-president and factory manager of the Smith Premier Works, has been promoted to the position of consulting engineer with the Union Typewriter Company, with headquarters in New York. While Mr. Barr will be connected with the general company he will still be associated with the Smith Premier Company of Syracuse.

Joseph G. Branch has been appointed president of The Branch Publishing Company, Chicago, Ill.

Edward W. Burgess has become identified with the Metzger Motor Car Company, Detroit, Mich. He was until recently mechanical engineer of the Whitlock Coil Pipe Company, Hartford, Conn.

Henry M. Byllesby has been elected president of the Civic Federation of Chicago, and chairman of its executive committee.

Theodore N. Case, recently chief engineer of the Kerr-Murray Mfg. Co., Fort Wayne, Ind., expects to purchase and to operate an irrigated farm in the Klamath project of the U. S. Reclamation Service, and incidentally to manufacture and install acetylene gas apparatus in that vicinity.

William L. Cathcart has contributed an article on Heat Losses from Steam Pipes to the November issue of *Cassier's Magazine.*

George E. Chamberlain of La Grange, Ill., has accepted the presidency of the Lewell Mfg. Co., Chicago, Ill.

Eugene Childs, formerly connected with the Trimont Mfg. Co., Roxbury, Mass., has been made president and general manager of the Springfield Drop Forge Co., Springfield, Mass., recently acquired by the Lakeside Forge and Wrench Co., Springfield, Mass.

Peter Eyermann has resigned his position with the Du Bois Iron Works, Du Bois, Pa., as chief engineer, and accepted an engagement with the Austrian steel works at Witkowitz, Austria.

Aime L. G. Fritz, until recently associated with Ford, Bacon & Davis, New York, has entered the service of the Tee Square & Triangle Co., Newark, N. J.

Chester B. Hamilton, Jr., has accepted a position with Smith, Kerry & Chace, Toronto, Ont.

Clarence H. Helvey has become connected with the Republic Motor Car Company, Hamilton, O. He was formerly with the Hamilton Engineering Company, Hamilton, O.

Walter G. Holmes, formerly with the American Sterilizer Co., Erie, Pa., has been made chief draftsman of the Linderman Machine Co., Muskegon, Mich.

Chas. M. Jarvis, vice-president of the American Hardware Corporation, New Britain, Conn., has been elected a director of the Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.

James McNaughton has been elected a director of the Colorado Fuel & Iron Co.

R. S. deMitkiewicz, formerly with the Fairbanks Company, in gas power work, has become connected with the New York office of the Alden, Sampson Mfg. Co., of Pittsfield, Mass.

John N. Mowery, mechanical engineer of the Lehigh Valley Railroad, South Bethlehem, Pa., has been transferred to Auburn, N. Y., in the capacity of assistant master mechanic.

George A. Orrok delivered a lecture on The Gas Engine in Relation to Blast Furnace Practice, before the November 10 meeting of the Society of Engineers of Eastern New York.

R. B. Owens, formerly professor of electrical engineering, McGill University, Montreal, P. Q., has become associated with the Southern Power Company, Charlotte, N. C.

T. Elliott Payson, consulting engineer, Jersey City, N. J., has accepted a position as superintendent of works with the Edengraph Mfg. Co., New York.

Chas. C. Phelps, formerly associated with the Gage Publishing Co., New York, has been appointed editor of *Steam*, New York.

Auguste L. Saltzman, consulting engineer, East Orange, N. J., has accepted a position with Walter Scott & Co., in charge of the drafting department.

Richard A. Smart has assumed the position of works manager of the Oliver Chilled Plow Works, South Bend, Ind. He was formerly assistant manager of works of the Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

William H. Smead has accepted a position with the General Fire Extinguisher Company, Warren, O. Mr. Smead was formerly associated with the Proximity Mfg. Co.'s Mills, Greensboro, N. C.

John Sturgess, formerly general manager of the Lombard & Replogal Governor Co., Akron, O., has become associated with the Platt Iron Works Company, Dayton, O., as Western representative.

E. H. Symington, formerly manager Western sales of the T. H. Symington Co., Chicago, Ill., is now located at the Rochester, N. Y., plant as works sales manager of the company.

Godfrey M. S. Tait will present a paper on Gas Power Plants at the November 16 meeting of the Modern Science Club, Brooklyn, N. Y.

Max E. R. Toltz, formerly located at the Chicago, Ill., office of the Manistee & Grand Rapids R. R., is now with the St. Paul, Minn., office. Mr. Toltz is general manager of the company.

Charles Waterman, formerly with the Maxwell Briscoe Motor Co., New Castle, Ind., has been appointed superintendent of the Southern Motor Works, Jackson, Tenn.

H. C. Whitehurst, with the firm of Evans, Almirall & Co., New York, has been placed in charge of that company's new branch office at Richmond, Va.

G. A. Young, assistant professor mechanical engineering, Purdue University, has taken a leave of absence and will spend a year in the Graduate School of Harvard University. Professor Young is taking some special work in the line of research in thermodynamics.

EFFICIENCY TESTS OF STEAM-TURBINE NOZZLES

By Prof. Frederick H. Sibley, University, Ala.
Member of the Society

T. S. Kemble,[1] Cleveland, O.
Non-Member

In 1905 a series of tests was begun at Case School of Applied Science, Cleveland, O., to determine the proper proportions and the efficiencies of steam-turbine nozzles for given steam conditions. The final tests, from which the results given herewith are derived, were made in an apparatus designed by T. S. Kemble, of the Chase Machine Co., of Cleveland. The writers spent about two years on these tests, and through the generosity of the company and the facilities afforded at Case School, were able to procure apparatus of considerable precision.

THEORY OF NOZZLES

2 By the theory of steam nozzles, a given weight of steam must pass all sections of the nozzle in the same time and the nozzle should be so constructed that the expansion will take place between the given initial and terminal pressures and wholly within the nozzle, the steam filling it completely at all sections. The available heat energy of the steam will then all be converted into kinetic energy and the efficiency will be a maximum. By efficiency we understand the kinetic energy of the jet per unit mass, divided by the available heat energy of the steam per unit mass.

3 To find the correct relation between the length and the cone angle of the nozzle, that the efficiency may be a maximum, is the problem to be determined experimentally. Let

[1] T. S. Kemble, Experimental Engineer for the Chase Machine Company, Cleveland, O.

All papers are subject to revision.

W = weight of steam flowing in pounds per second.
V = velocity of the jet in feet per second.
M = mass.
F = reaction in pounds.
g = acceleration due to gravity at Case School = 32.16015.
K = kinetic energy of the jet in foot-pounds or B.t.u.
E = total available heat energy of the steam.
Efficiency = $K \div E$.

4 From Mechanics we have: $K = \frac{1}{2}MV^2$ and $M = W \div g$. If $W = 1$ lb., then

$$K \text{ (the B.t.u.)} = \frac{V^2}{2g \times 778}$$

also

$$V = \frac{Fg}{W} \quad \text{for any flow}$$

F is the factor to be determined by experiment.

METHODS SUGGESTED

5 Three methods may be suggested for determining the efficiency of steam nozzles.

- *a* By measuring the force of the jet when allowed to impinge on an external surface.
- *b* By investigating the character of the jet with a search tube inserted axially in the nozzle.
- *c* By measuring the reaction of the nozzle when a jet of steam is flowing through it.

6 The first method involves complications which tend to cast some doubt upon the results obtained. The force upon the external surface may be modified by the character of the surface, by eddying and steam friction, and by the distance traveled by the jet after leaving the nozzle and before it reaches the surface. When the surface used is a flat plate perpendicular to the axis of the jet, the force may even vary from a maximum to a negative value according to the relative location of the plate and nozzle.

7 The second method was tried in a series of experiments to find the pressure in the jet at various sections of the nozzle. A search tube was inserted axially in the nozzle and the relation between pres-

sure and flow was compared with the theoretical relation, as calculated and plotted from the steam tables. The first search tube used was of drawn copper $\frac{1}{16}$ in. in outside diameter and $\frac{1}{64}$ in. in inside diameter. One end was closed and the other connected to a mercury column. A $\frac{1}{64}$-in. hole was drilled through the search tube at right angles to its axis. The tube was so actuated as to bring the holes into any desired section of the nozzle, and the pressure shown by the mercury gage was recorded.

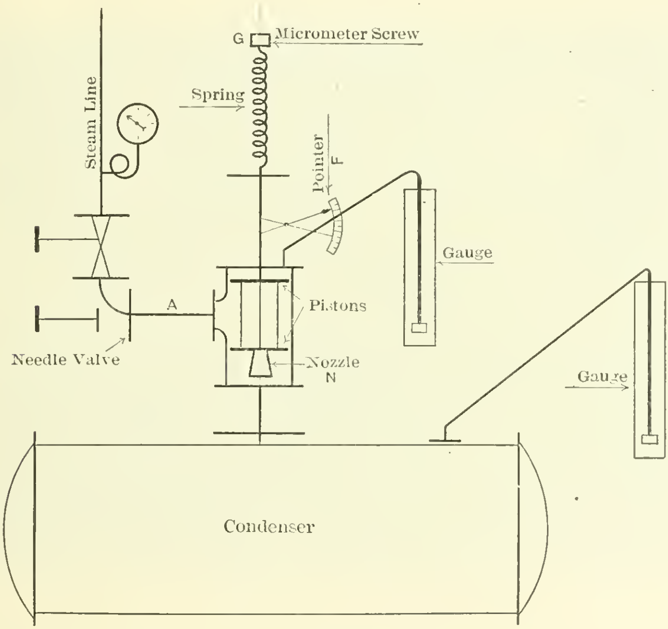

FIG. 1 DIAGRAM OF PISTON APPARATUS

8 This search tube was a failure, the pressures recorded being greatly at variance under identical conditions. This trouble was attributed to the capillary action on the condensed steam in the tube of the very small longitudinal hole.

9 A brass tube $\frac{3}{32}$ in. outside diameter and $\frac{1}{16}$ in. inside diameter gave results much more nearly consistent but not nearly accurate enough to determine the efficiencies at the various sections of the nozzle.

10 The third method provided for the determination of the reaction of the jet in the nozzle, and apparatus was constructed for this purpose, differing in detail as follows:

1 By fastening the nozzle into the outer face of one of a pair of rigidly connected pistons suspended in a cylinder. Steam entering between the pistons and flowing out through the nozzle would produce a measurable reaction.

2 By using a flexible steel tube suspended freely by one end and having the nozzle attached to a chamber at the other

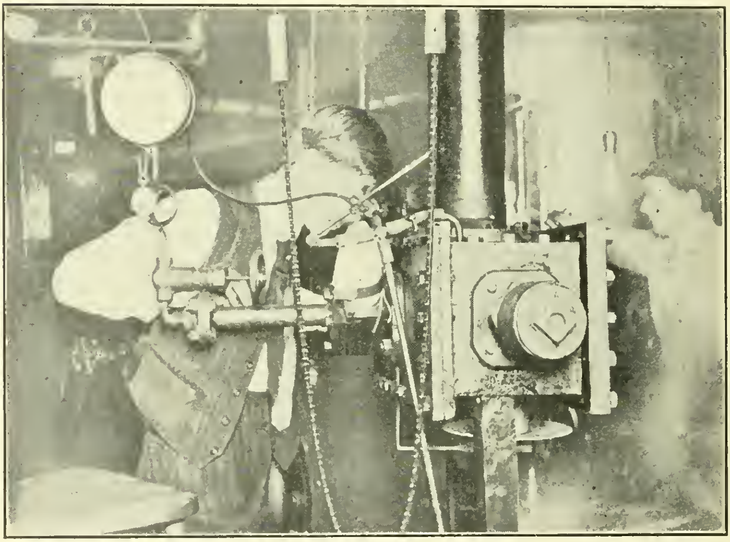

FIG. 2 FLEXIBLE TUBE APPARATUS FOR MEASURING REACTION OF JET

end with its axis perpendicular to the axis of the tube. Steam flowing downward through the tube and out of the nozzle would cause the tube to deflect with a measurable force.

PISTON METHOD

11 Fig. 1 is a diagram of the piston apparatus, having floating pistons rigidly connected with one another. High-pressure steam entered between the pistons at A and flowed out through the nozzle N_2 to the condenser. The pistons were hung on the end of a calibrated spring enclosed within the exhaust steam space and their

weight put an initial tension in the spring. The total movement allowed the pistons was about $\frac{1}{16}$ in. and for convenience this movement was multiplied by the needle F in the ratio of ten to one. When steam flowed through the nozzle the reaction of the jet relieved part of the tension on the spring and the corresponding decrease of elongation was measured by the micrometer nut and screw and expressed in pounds.

12 As first constructed, the pistons moved quite freely when no steam was flowing, but when the steam was turned on the static friction increased so rapidly as to make accurate results impossible. When the diameter of the pistons had been reduced to the point where the friction became manageable, the leakage of steam past them became so great as to cause considerable trouble. Furthermore, condensed steam gathered on top of the upper piston, creating another source of error, because it was impossible to know the quantity present at any given instant and so to make a corresponding correction. Modification of this apparatus in the attempt to overcome these difficulties would have amounted almost to rebuilding and before doing this another method was tried with such success that it was not considered necessary to return to the old one.

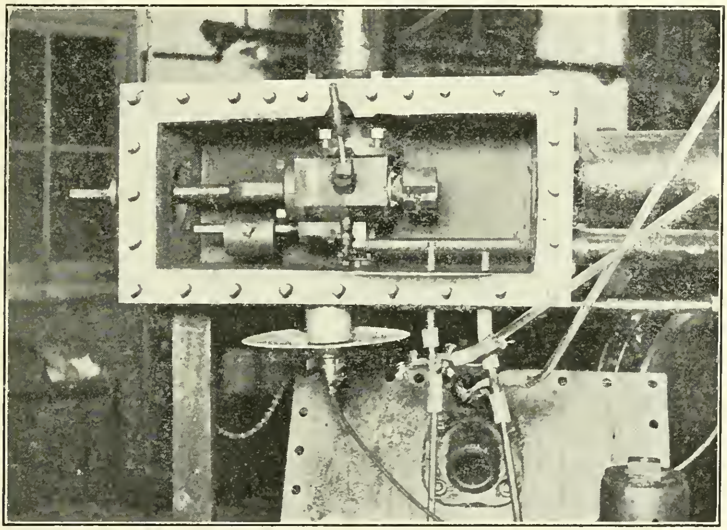

Fig. 3 Interior of Box Containing Flexible Tube Apparatus

FLEXIBLE TUBE APPARATUS

13 The flexible tube apparatus (shown in Figs. 2 to 5) was then tried with such success that it was not considered necessary to return to the piston apparatus. This apparatus was designed with a special view to combining the search-tube and reaction methods, by which means we hoped to obtain results more accurate than would result from either method alone.

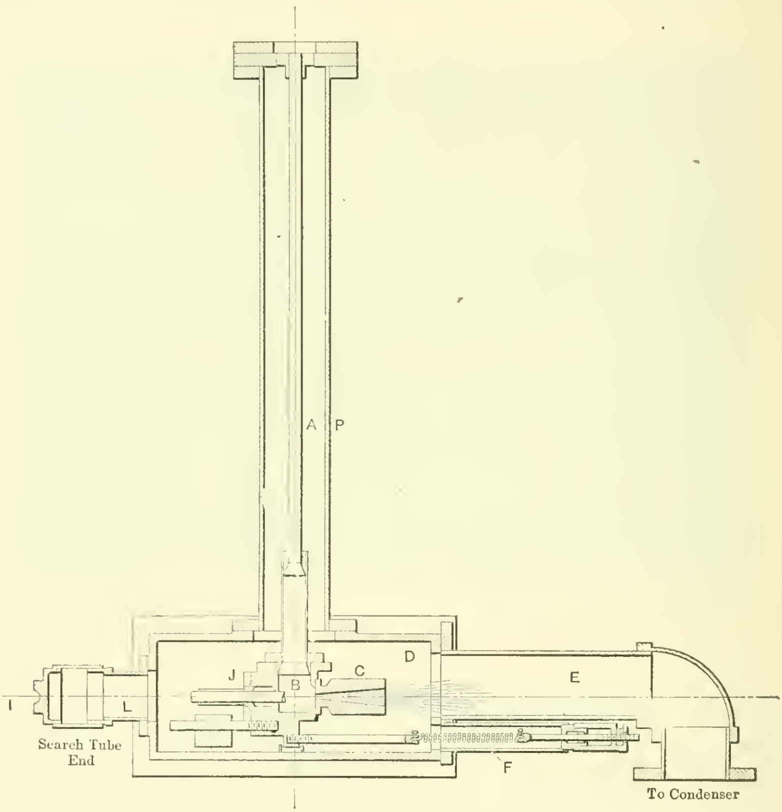

Fig. 4 Section of Flexible Tube Apparatus

CONDITIONS OF TESTS

14 All tests were run at night, that there might be no interference with other work being conducted in the laboratory and boiler room. Steam was generated in a 125-h.p. Babcock & Wilcox boiler at a

pressure of 155 lb. gage with a variation of not more than 2 lb. up or down. There was about 50 deg. fahr. superheat at the boiler, which was connected with the testing apparatus by about 55 ft. of 5-in. pipe and 25 ft. of 4-in. pipe.

15 In the main steam pipe was located an angle needle-valve operated by a sprocket wheel and chain (Fig. 2) which made it possible to hold the nozzle feed-pressure very constant. From this point the steam passed downward through the tube A to the chamber B, (Fig. 4) thence through the nozzle C into the box D, and on through the passage E to the condenser.

16 The upper end of the tube A was screwed into a diaphragm on the lower flange of the angle valve. At its lower end it supported the chamber B which was allowed to move between stops restrained only by the stiffness of the tube and of the spring F. The motion of the chamber B was indicated by a needle which multiplied the motion

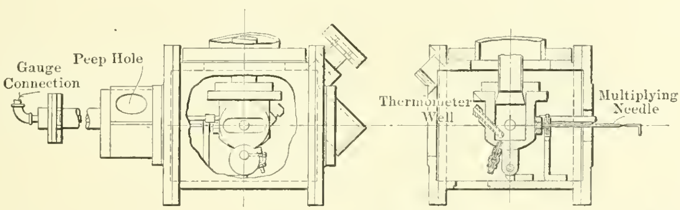

FIG. 5 END VIEWS OF SEARCH-TUBE END AND OF CONDENSER END

about ten to one. The spring F was operated by a micrometer nut and screw and was calibrated *in place* by known weights hanging on a flexible wire cable which extended from the back of the chamber in the line of the nozzle axis and down over a ball-bearing sheave. The tube A, the chamber B and the nozzle, were all enclosed in the vertical pipe P and the box D, and the vacuum surrounding them was greater than that in the condenser owing to the "augmenter" action of the steam jet entering the passage E to the condenser.

17 The initial temperature of the steam was shown by a thermometer inserted in a well in the chamber B and observed through a glass in the box D. A steam gage was connected by a flexible tube to the chamber B. The vacuum in the condenser and in the box D was shown by mercury columns, and the other column was joined by a flexible connection to a hole drilled as near as possible to the muzzle of the nozzle and perpendicular to the wall. All these connections to the mercury columns were of glass tubing with rubber couplings

which allowed the moving parts to swing freely without friction and made it easy to observe any accumulation of moisture, and by breaking the connection air could be let through to dry them quickly.

FORMS OF NOZZLE TESTED

18 The exact dimensions of the nozzles are shown in Fig. 6 and Fig. 7. They were all of machinery steel, bored taper, and had

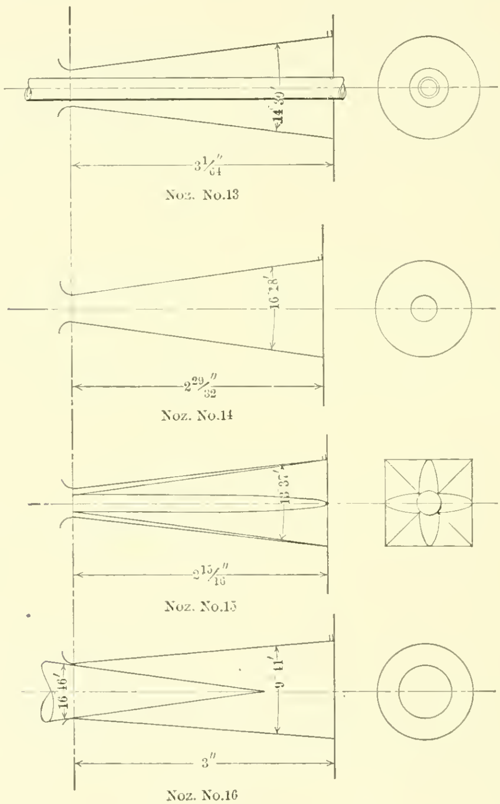

Fig. 6 Forms of Nozzles Tested

entrances rounded off with a hand tool to approximately $\frac{1}{8}$ in radius. All nozzles except No. 15 and No. 18 were bored smooth and polished. Nos. 10, 11 and 12 were identical except as to length and angle of divergence. No. 18 was like No. 11 except that it was finished rough

on the inside between the throat and muzzle, the finishing chip being made with a threading tool having an angle of 120 deg., and cutting 90 threads per inch. No. 14 and No. 15 were identical except that whereas No. 14 was bored taper, No. 15 was made in halves, and after

TABLE 1 DIMENSIONS OF NOZZLES IN FIG. 6

Nozzle No.	Gross Diameter Throat inches	Gross Diameter Outlet inches	Net Area Throat sq. ins.	Net Area Outlet sq. ins.	Length inches	Angle of Divergence
13	0.3949	1.156	0.0734	1.0005	$3\frac{1}{64}$	14° 30′
14	0.3038	1.128	0.0725	0.9993	$2\frac{29}{32}$	16° 18′
15	0.3038	1 in. sq.	0.0725	1.0000	$2\frac{15}{16}$	13° 37′
16	0.625	1.1315	0.0725	1.0055	3	9° 41′

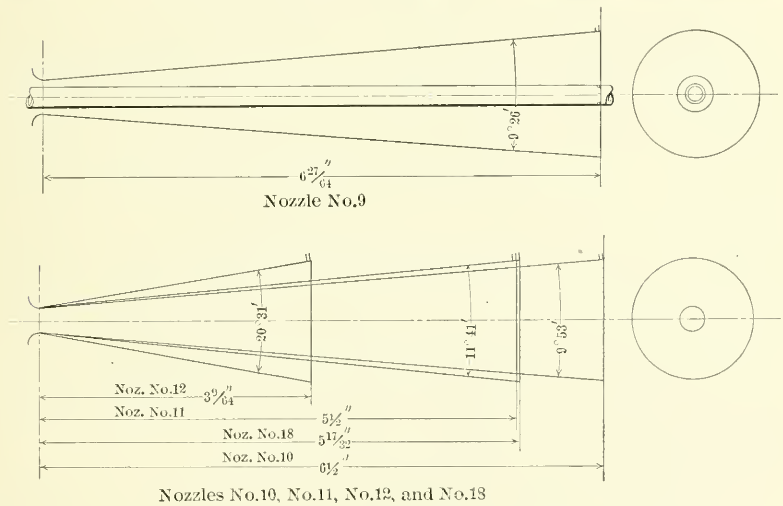

Fig. 7 Forms of Nozzles Tested

TABLE 2 DIMENSIONS OF NOZZLES IN FIG. 7

Nozzle No.	Gross Diameter Throat inches	Gross Diameter Outlet inches	Net Area Throat sq. ins.	Net Area Outlet sq. ins.	Length inches	Angle of Divergence
9	0.3940	1.4505	0.0728	1.6033	$6\frac{27}{64}$	9° 26′
10	0.3039	1.4240	0.0726	1.5926	$6\frac{1}{2}$	9° 53′
11	0.3039	1.4231	0.0725	1.5907	$5\frac{1}{2}$	11° 41′
12	0.3056	1.4241	0.0733	1.5930	$3\frac{9}{64}$	20° 31′
18	0.3039	1.4225	0.0725	1.5893	$5\frac{17}{32}$	11° 36′

being bored taper these halves were separated and milled longitudinally with a 90-deg. cutter, the cut beginning just beyond the throat and running deeper toward the muzzle, where the section becomes square, with the same area as the muzzle of No. 14. No. 16 was like No. 14 but had a larger throat area so that a needle point could be introduced to give the same net area as No. 14. No. 9 and No. 13 are search-tube nozzles made with throat and muzzle areas large enough so that the net areas, with the search tube in place, were equal to the net areas of the corresponding "reaction" nozzles. No. 9 corresponds to Nos. 10, 11, 12 and 18. No. 13 corresponds to Nos. 14, 15 and 16. The dimensions of the nozzles are given in Tables 1 and 2.

FLOW TESTS

19 Numerous tests were made to determine the rate of flow of steam through the various nozzles. Fig. 8 shows the results of these tests plotted to a scale of pounds flow per hour. The variations in flow are probably due principally to moisture in the steam, and to some extent to leakage from the water to the steam side of the condenser. The condenser was tested and at no time showed a leak exceeding two pounds per hour. There was sometimes a trace of superheat at the nozzle entrance, and this increased with an increase in the volume of flow. At pressures of less than 145 lb., moisture was probably always present. For this reason the values used in the calculations were the mean flow-values for 145-lb. pressure, and a trifle less than the mean for the lower pressures. It is to be regretted that we were unable to procure a calorimeter of sufficient accuracy for our purpose.

20 In Fig. 8 the results are given in pounds per hour for the four initial pressures. Each small circle represents the result of one flow test of from 15 min. to 30 min. duration. The vertical dotted lines represent the flow values that were used in the efficiency calculations. The flow values for the irregularly shaped nozzles are a little higher than the others, as is shown in the upper part of the diagram. The diagonal lines simply connect together the results found in the same test. For example, the five circles along the lowest line of the chart represent the values found for nozzle No. 9 on January 17 and 18, 1908. The vertical scale is not important although each initial pressure is located higher up on the diagram than the preceding one as a matter of convenience.

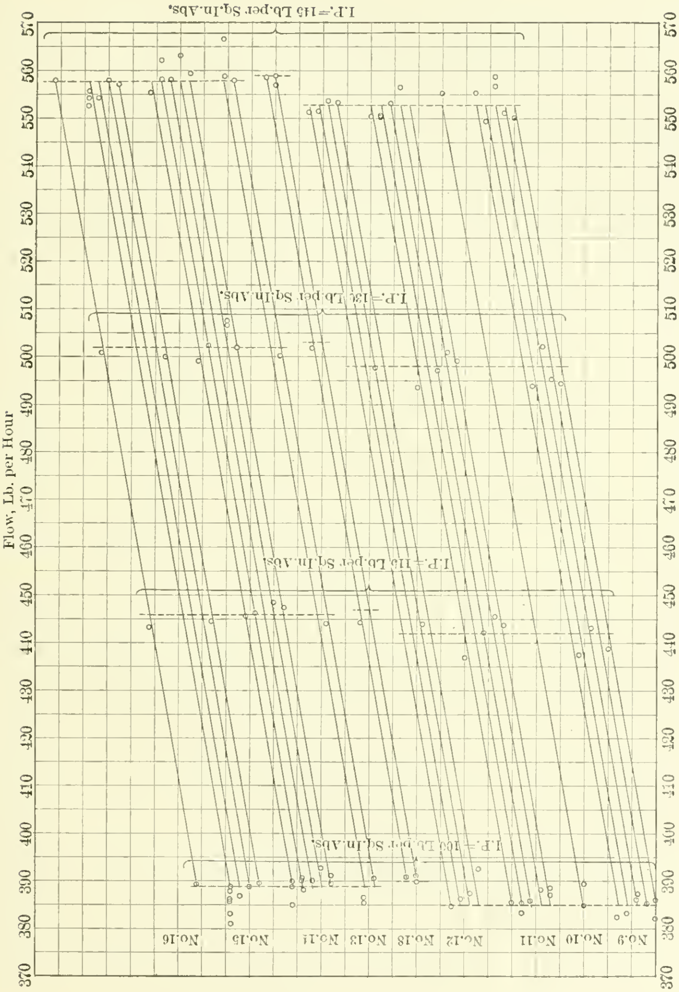

Fig. 8 Weight of Steam Flowing through Nozzles on Different Dates

SPRING CALIBRATIONS

21 The accuracy with which the reactions were determined depended largely on the care taken in calibrating the springs. These calibrations were first made with the spring in place in the apparatus, and at the room temperature of about 85 deg. fahr. The readings were taken while gradually loading the spring to 25 lb. and then unloading it, repeating the operation a great number of times and taking average extension under any given load as the true extension for that load. The average extension under a load of 25 lb. was 1.4875 in., or 0.0595 in. per lb. In cooling off, tube A, Fig. 4, seemed to warp a little, so that after about two minutes there was a decrease in the initial extension of the spring of about 0.0025 in. As it took about two minutes to shut off the steam and get the initial extension after each reaction reading, the spring extensions were all corrected by this amount.

22 Another factor which affected the spring calibration was the change in temperature of the spring itself. A thermometer was inserted in the spring casing and the spring calibrated at various temperatures by observing the temperature and extensions simultaneously. From these temperature calibrations a correction factor $l[0.0002423\ (t_2 - t_1)]$ was obtained and used to correct the reactions found by using the factor 0.0595 in. per lb.

23 After the thermometer had been inserted in the spring casing it was noted that as the reaction test progressed the temperature at first increased and then remained nearly constant regardless of moderate changes in initial and terminal pressures. This was due to the fact that the box D stood open and cooled off between tests and then warmed up gradually when the steam was turned on. The average temperature in the spring casing was about 135 deg. fahr., or 50 deg. higher than the room temperature at which the original calibration was made. All the reactions found before this thermometer was in place were corrected on the assumption that the spring temperature was 135 deg. fahr. While this did not eliminate the error due to the fact that the temperature increased during the first part of each test, it did bring the average pretty close to what it should be.

24 Corresponding readings of spring extensions at the beginning and end of tests were lower and higher respectively than the average extension. This was due to the above-mentioned difference in spring temperature. When the spring temperature was read simultaneously with the spring extension this difference disappeared.

SEARCH-TUBE TESTS

25 After completing the flow tests and the spring calibrations one other factor remained to be determined before the reaction tests could be made. This was the determination of the pressure at the muzzle of the nozzle.

26 *The reaction of any nozzle is equal to the summation of all the components, parallel to its axis, of the pressures within the nozzle and in the chamber from which it leads.* If the pressure of the medium surrounding the nozzle and the chamber is equal to that in the plane of the muzzle, then the reaction as shown by the pull on the spring is the true reaction. If the pressure of the surrounding medium is greater than that in the plane of the muzzle it will decrease the apparent reaction, and if the pressure of the surrounding medium is less than that in the plane of the muzzle it will increase the apparent reaction. The amount of such increase or decrease will be equal to the difference in the unit pressure multiplied by the area of the muzzle. The true reaction of the nozzle is equal to the pull of the spring plus or minus this pressure difference.

27 The demonstration of this proposition possibly differentiates these experiments from those heretofore published, as the writers do not know of any other case where the combination has been used in this manner.

28 The muzzle pressure was found by using the search tube with nozzles No. 9 and No. 13. The search tube here used was a selected piece of cold-drawn Shelby tube $\frac{1}{4}$ in. in outside diameter and $\frac{3}{16}$ in. in inside diameter, with six holes $\frac{1}{32}$ in. in diameter drilled perpendicular to the axis. The outside of the tube was polished to micrometer measurement. The chamber *B* was rigidly connected to the back wall of the box *D* by the distance piece at *J* (Fig. 3). The rear end of the search tube was encased and supported by a tube at *L* which had on its outer surface a thread fitted with a micrometer nut, and passed through the distance piece holding the search tube in the axis of the nozzle.

29 The holes in the search tube were located in the same plane as the hole in the wall of the nozzle. One gage was connected to the box *D*, another to the hole in the wall of the nozzle, and a third to the rear end of the search tube. Simultaneous readings of these gages were taken with varying pressures in the box. These readings were plotted in Fig. 9 and Fig. 10.

30 The diagonal lines represent the box pressures, which were

varied from 0.5 lb. to 2 lb. absolute. The larger circles represent the pressures at the rim of the nozzle and the smaller circles that at the center of the nozzle. These are plotted for the four initial pressures as found on different dates. The dotted horizontal lines represent the muzzle pressures used in determining the true reaction. For example, on May 22 and 23, with an initial pressure of 100 lb. under a box pressure of 0.8 lb. absolute the terminal pressure at both rim and center of the nozzle was 0.7 lb. absolute; 0.648 was the average terminal pressure used in the calculations.

31 The first tests seemed to indicate a higher pressure in the center of the stream than in the rim. Later a leak in the search-tube connections was discovered and repaired, and the tests repeated. This time the rim readings were constant, while the search-tube readings came down toward the rim readings, showing that they had been affected by the leak. More careful repairs still further reduced the leak and the search-tube readings, until there appeared to be no actual difference in pressure at the rim and at the center of the stream. It was decided to use the rim readings where a difference remained as it was hardly possible to keep the search-tube connections perfectly tight throughout a night's run, and error seemed more likely than in the rim readings.

32 Fig. 9 and Fig. 10 show that the pressure in the center of the stream remains constant with considerable variation in pressure in the box *D*, and the pressure at the rim of the stream remains constant until the pressure in the box rises somewhat above that shown in the search tube, at which time the pressure works gradually in along the rim without at first affecting the center of the stream.

33 The terminal pressures taken from these tests were further corrected by the difference between the pressure in this plane and in the exact plane of the muzzle. This correction involved the subtraction of only 0.01 lb. per sq. in. for No. 9, and 0.03 lb. per sq. in. for No. 13.

REACTION TESTS

34 In making reaction tests the following routine was observed: The barometer was read with every observation, and corresponding corrections made so that the initial absolute pressure used should be exactly 145, 130, 115 and 100 lb. per sq. in. This was for convenience in making computations. One observer maintained a constant initial pressure by manipulating the needle valve in the steam pipe. A second observer maintained a constant vacuum in the box *D* by

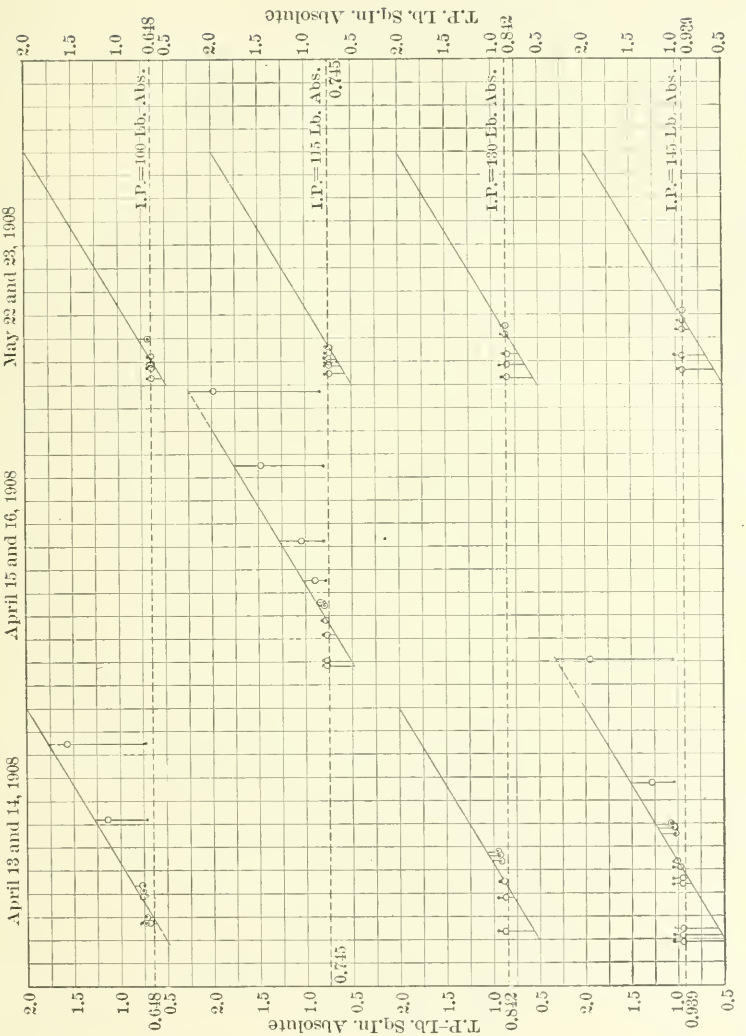

FIG. 9. EFFECT UPON THERMAL PRESSURE OF NOZZLE, PRODUCED BY VARYING PRESSURE IN BOX IN WHICH NOZZLE WAS SUSPENDED

THIS IS FOR NOZZLE NO. 9, WHICH CORRESPONDS TO NO. 11.

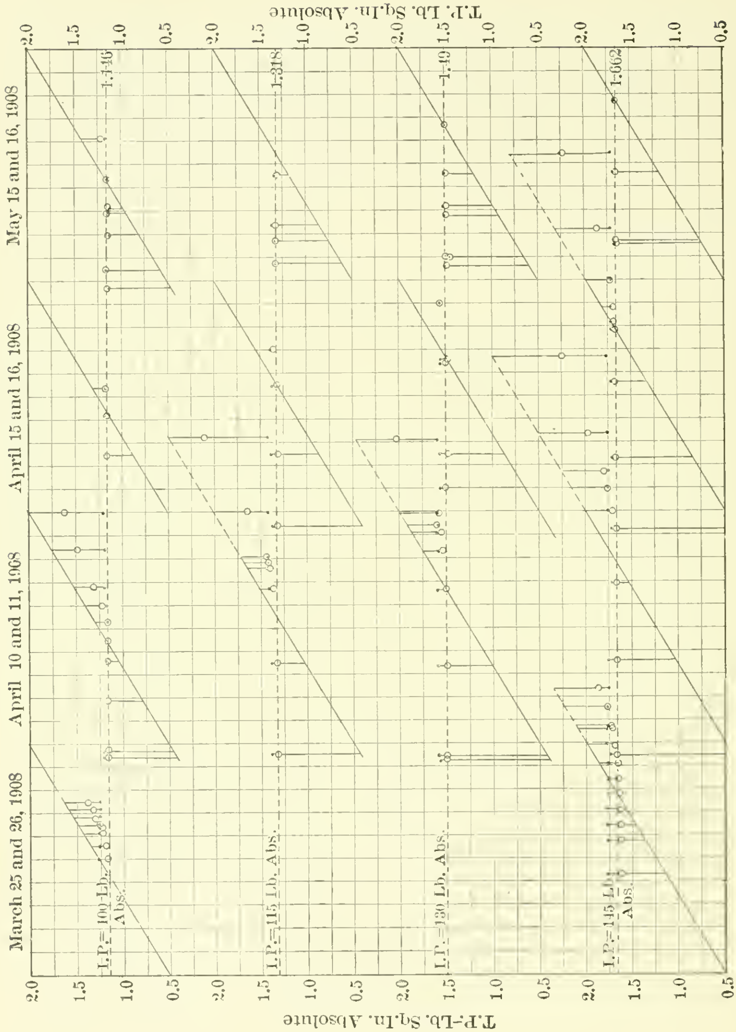

FIG. 10 EFFECT ON THERMAL PRESSURE OF NOZZLE, PRODUCED BY VARYING PRESSURE IN BOX IN WHICH NOZZLE WAS SUSPENDED

THIS IS FOR NOZZLE NO. 13, WHICH CORRESPONDS TO NO. 14.

manipulating the valves leading to the pump and condenser. A third operated the micrometer screw which registered the spring extension and thus held the multiplying-needle opposite an index at the center of its travel. A fourth and sometimes a fifth man read gages, and one man was generally occupied in moving about behind the observers to check observations.

35 As the reaction of the jet forced the chamber B back against

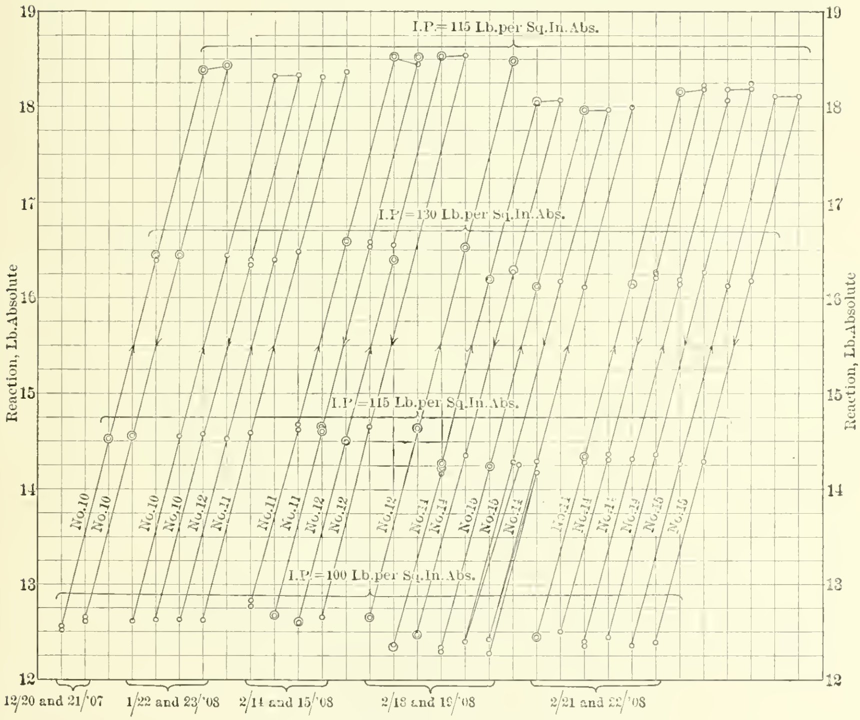

Fig. 11 Preliminary Reaction Tests

the tension of the spring, the micrometer screw was worked forward until the tension in the spring balanced the reaction and the multiplying-needle indicated that B was swinging freely in the central position. When the needle remained quiet for an instant in this position the observer gave a signal and the thermometer and gages were read simultaneously. After each reading the steam was shut off, and the position of the micrometer screw with the needle in the central position was noted. The difference between this position and

that when the steam was flowing gave the elongation of the spring due to the reaction.

36 It will be noted that friction has been entirely eliminated in this apparatus, except for the trifling amount due to the movement of the multiplying-needle.

CALCULATION FOR EFFICIENCY

37 A series of preliminary reaction tests was run on all of the nozzles with the result that nozzles No. 11 and No. 14 were selected as

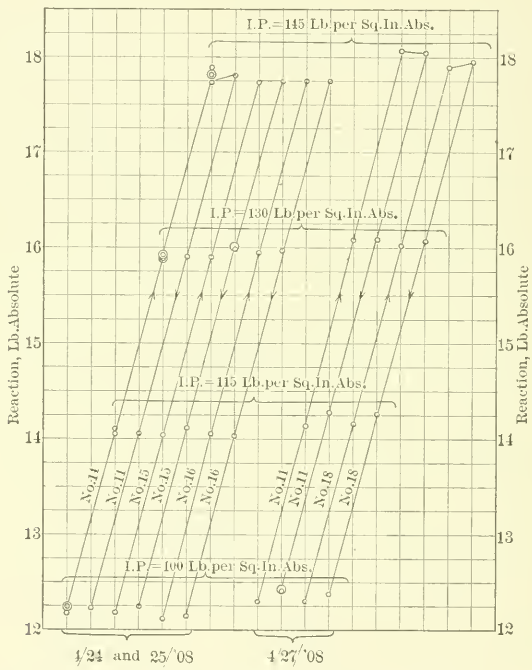

Fig. 12 Comparison of Tests on Nozzles 14, 15 and 16 with those on Nozzles 11 and 18

representative for future tests. The results of the preliminary tests upon these nozzles are given in Fig. 11. Exhaustive tests of long duration were then made upon nozzles No. 11 and No. 14 with the results shown in Fig. 13 and Fig. 14, and in Tables 3 and 4. Fig. 12 shows the comparative results of certain of the tests.

38 In Fig. 11 and Fig. 12 the reactions in pounds absolute are grouped together horizontally. The reactions are shown for each

of the four initial pressures. The vertical scale is four lines to the pound. The horizontal scale is not important, the initial pressures being placed diagonally over each other as a matter of convenience. The diagonal lines connect the reactions of a single nozzle at the various pressures. The arrowheads indicate whether the reactions

TABLE 3 COMPUTATION OF EFFICIENCY, NOZZLE NO. 11

I. P. Abs.	T. P. Lbs. per Sq. In. Abs.	Reaction	Flow Lbs. per Hr.	Flow Lbs. per Sec.	Vel.	B.T.U.₁	B.T.U.₂ Table	Eff. %
145	0.929	18.134	553	0.1536	3796	288.0	317.4	90.75
145	1.029	17.974	553	0.1536	3763	283.0	312.5	90.55
145	0.829	18.294	553	0.1536	3830	293.1	322.7	90.84
145	0.929	18.134	558	0.1550	3762	282.9	317.4	89.13
145	0.929	18.134	548	0.1522	3831	293.3	317.4	92.41
145	0.929	18.234	553	0.1536	3817	291.2	317.4	91.75
145	0.929	18.034	553	0.1536	3776	284.9	317.4	89.75
130	0.832	16.244	498	0.1383	3776	285.0	315.4	90.36
115	0.735	14.351	442	0.1228	3759	282.4	313.6	90.03
100	0.638	12.45	385	0.1069	3744	280.1	311.5	89.91
100	0.738	12.29	385	0.1069	3696	273.0	304.6	89.63
100	0.538	12.61	385	0.1069	3792	287.4	319.5	89.94
100	0.638	12.45	390	0.1083	3696	273.0	311.5	87.62
100	0.638	12.45	380	0.1056	3793	287.5	311.5	92.29
100	0.638	12.55	385	0.1069	3774	284.6	311.5	91.36
100	0.638	12.35	385	0.1069	3714	275.6	311.5	88.47
Assuming 2 per cent moisture								
145	0.929	18.134	553	0.1536	3796	288.0	311.9	92.35
130	0.832	16.244	498	0.1383	3776	285.0	310.0	91.93
115	0.735	14.351	442	0.1228	3759	282.4	308.2	91.62
100	0.638	12.45	385	0.1069	3744	280.1	306.1	91.51

B.t.u. are given only to the nearest tenth, and for this reason efficiencies are not accurate in second decimal place.

B.t.u.$_1$ = equivalent of kinetic energy of jet in B.t.u.

B.t.u.$_2$ = available heat energy of steam.

shown on that line were taken when the pressure was increasing or decreasing. The circles represent the actual reactions in pounds as plotted from the tests. Two circles occurring together indicate that two independent readings of the reaction were taken at the same time. A larger circle outside the small one indicates the reading preferred.

39 Fig. 13 shows graphically the result of a complete series of reaction tests on nozzle No. 11, which is practically the same as nozzles Nos. 9 and 13. The vertical scale is 20 lines to the pound, while the horizontal scale is 100 lines to the pound. The full diagonal lines connect together the observed reactions in pounds under a varying box pressure. The horizontal dotted lines connect together

TABLE 4 COMPUTATION OF EFFICIENCY, NOZZLE NO. 14

Showing Effect of Error in Determination of Terminal Pressure Flow or Reaction

I. P. Abs.	T. P. Lbs. per Sq. In. Abs.	Reaction	Flow Lbs. per Hr.	Flow Lbs. per Sec.	Vel.	B.T.U.$_1$	B.T.U.$_2$ Table	Eff. %
145	1.632	17.821	558	0.1550	3698	273.2	289.8	94.28
145	1.732	17.721	558	0.1550	3677	270.2	286.7	94.23
145	1.532	17.921	558	0.1550	3718	276.3	293.0	94.30
145	1.632	17.821	563	0.1564	3665	268.4	289.8	92.61
145	1.632	17.821	553	0.1536	3731	278.2	289.8	95.99
145	1.632	17.921	558	0.1550	3718	276.3	289.8	95.34
145	1.632	17.721	558	0.1550	3677	270.2	289.8	93.22
130	1.46	15.977	502	0.1394	3685	271.3	288.2	94.15
115	1.288	14.147	446	0.1239	3672	269.5	286.5	94.07
100	1.116	12.295	389	0.1081	3659	267.6	284.7	93.99
100	1.216	12.195	389	0.1081	3630	263.3	280.3	93.92
100	1.016	12.395	389	0.1081	3689	272.0	289.3	94.01
100	1.116	12.295	394	0.1094	3613	260.8	284.7	91.62
100	1.116	12.295	384	0.1067	3707	274.6	284.7	96.45
100	1.116	12.395	389	0.1081	3689	272.0	284.7	95.53
100	1.116	12.195	389	0.1081	3630	263.3	284.7	92.47
Assuming 2 per cent moisture								
145	1.632	17.821	558	0.1550	3698	273.2	284.7	95.97
130	1.46	15.977	502	0.1394	3685	271.3	283.1	95.84
115	1.288	14.147	446	0.1239	3672	269.5	281.5	95.74
100	1.116	12.295	389	0.1081	3659	267.6	279.7	95.67

B.t.u. are given only to the nearest tenth, and for this reason efficiencies are not accurate in second decimal place.

B.t.u.$_1$ = equivalent of kinetic energy of jet in B.t.u.

B.t.u.$_2$ = available heat energy of steam.

the same reactions after being corrected for the difference in pressure between the box and the muzzle of the nozzle. The dotted diagonal line represents the pressure in the muzzle of the nozzle as found with the search tube and is plotted to the same horizontal scale as the box pressure. When the box and terminal pressures are the same the apparent and corrected reactions are the same, as

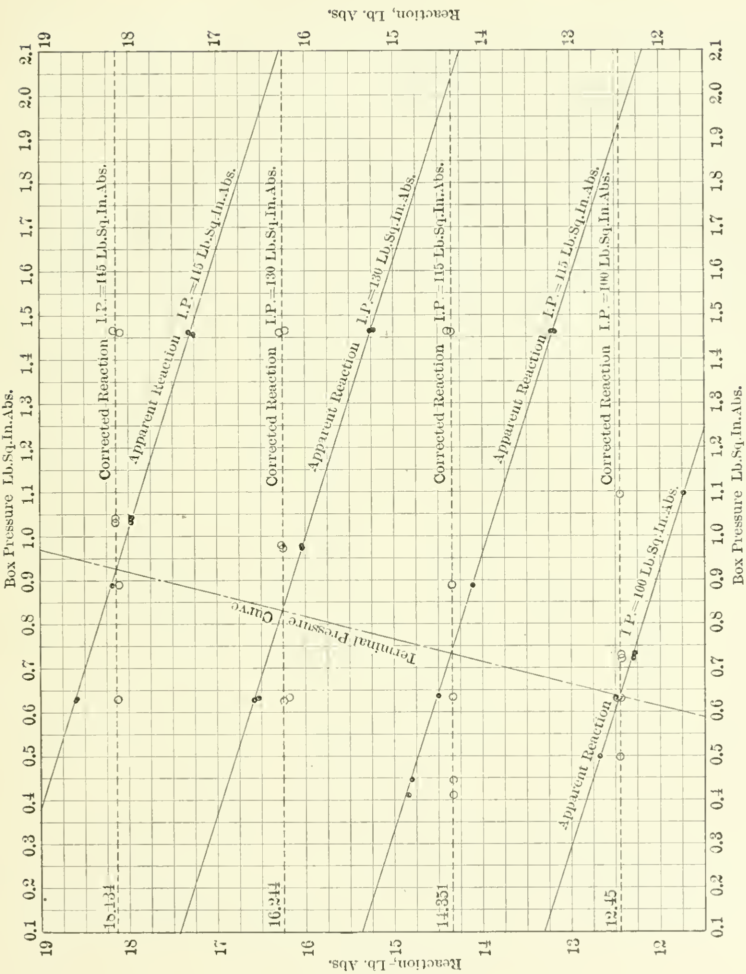

FIG. 13 REACTION TESTS OF NOZZLE NO. 11 WITH VARYING BOX PRESSURE

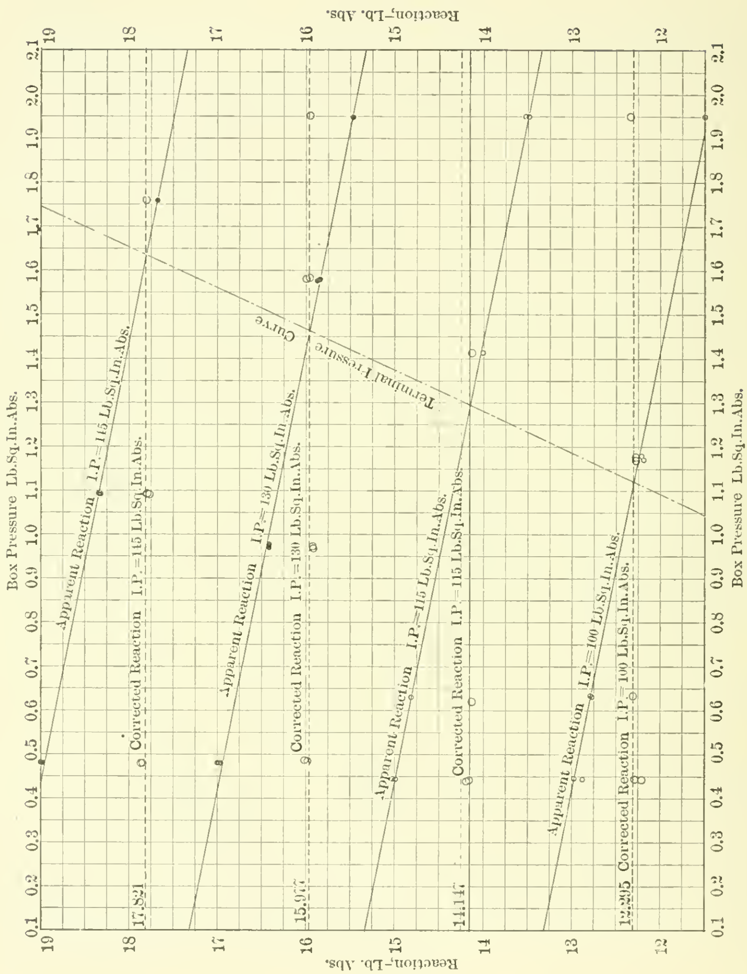

Fig. 14 Reaction Tests on Nozzle No. 14 with Varying Box Pressure

is shown by the intersection of the three lines. As the box pressure increases above that point where the terminal and box pressures were the same the apparent reaction falls below the true reaction, and as the box pressure falls below that point where the terminal and box pressures were the same, the apparent reaction rises above the true reaction. As an example, the terminal pressure at 115 lb. initial pressure is approximately 0.7341 lb. When the box pressure was increased to 0.89 the apparent reaction was 14.10 lb. To this apparent reaction was added the correction factor (difference in pressure × area of muzzle) to give the corrected reaction 0.14.351. Fig. 14 is like Fig. 13, the values being for nozzle No. 14.

40 The method of calculation may be illustrated by the following from nozzle No. 14 with an absolute initial pressure of 145 lb. per sq. in. The terminal pressure (See Fig. 10) is 1.662 lb. per sq. in., and deducting 0.03 this becomes 1.632 lb. per sq. in. The reaction (Table 1) is 17.821 lb. The flow is 558 lb. per hr. or 0.155 lb. per sec.

$$\text{Velocity} = V = \frac{\text{reaction} \times g}{\text{flow (lb. per sec.)}} = \frac{17.821 \times 32.16}{0.155} = 3697.6 \text{ ft. per sec.}$$

$$\text{B.t.u.}_1 = \text{kinetic energy of jet} = \frac{V^2}{2g \times 778} = \frac{3697.6^2}{2 \times 32.16 \times 778} = 273.22$$

$$\text{B.t.u.}_2 = \text{available energy (from steam table)} = 289.8$$

$$\text{Efficiency} = \frac{\text{B.t.u.}_1}{\text{B.t.u.}_2} = \frac{273.22}{289.8} = 0.9428 \text{ or } 94.28 \text{ per cent}$$

41 If the terminal pressure had been determined as 1.732 and no other factor changed, the true reaction as calculated would have been 17.721 instead of that shown in Table 3 and the resulting efficiency would be 94.23 per cent.

42 If the flow had been determined as 563 lb. per hr. with no other change of values the efficiency would have figured 92.61 per cent.

43 A reaction of 17.921 without other change would have given an efficiency of 95.34 per cent.

44 If we assumed 2 per cent of moisture, the efficiency would figure as 95.97 per cent.

45 The efficiency was also calculated by the search-tube method, by first plotting curves (similar to those shown in Fig. 15) showing

the relation between pressure and rate of flow per unit area of section, with adiabatic expansion and with various percentages of friction loss. The pressure and flow found by experiment were then plotted on this chart and the efficiency determined graphically by comparison.

46 The chart in Fig. 15 was designed for finding the nozzle efficiency by the search tube method. The vertical scale is four lines to the pound. The horizontal scale is 10 lb. per hour per line. The chart shows the relation between the flow in pounds per square inch of section and the pressure in any section of the nozzle, assum-

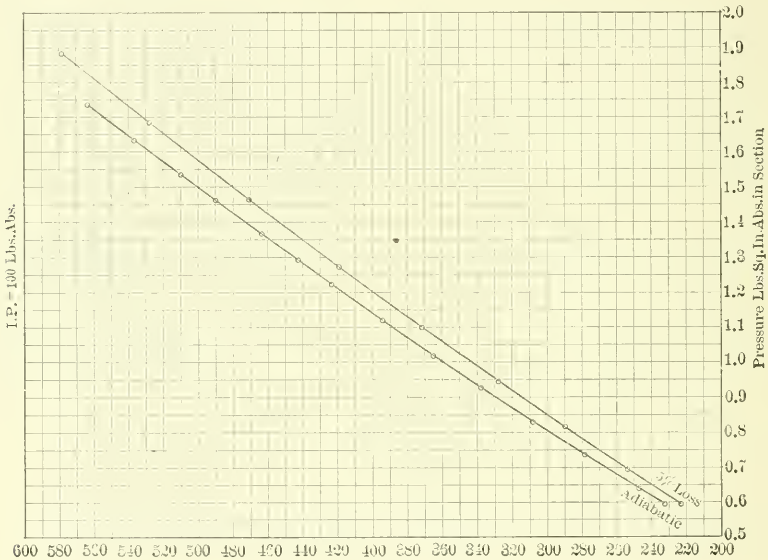

Fig. 15 Pressure-Flow Chart

ing adiabatic expansion for the lower curve and 5 per cent loss of heat for the upper one. The data for plotting these curves was obtained from the steam tables. By plotting the observed values of pressure and flow upon these sheets we are able to obtain a graphic solution for efficiency. For example, in the case of nozzle No. 9 the terminal pressure at 100 lb. initial pressure was found to be 0.638 lb. per sq. in. and the corresponding flow in pound per square inch of section is 238 ±. From the chart, assuming adiabatic expansion, under terminal pressure of 0.638 the flow would be 248 lb. and 238/248 is approximately 96 = the efficiency.

TABLE 5 SUMMARY OF CALCULATIONS OF EFFICIENCY FOR NOZZLES 9, 11, 13 AND 14

Nozzle No.	I. P. Lbs. per Sq. In. Abs.	T. P. Lbs. per Sq. In. Abs.	Flow Lbs. per Hour	Reaction Pounds	Theoret. B.t.u. per Lb.	Calcul. B.t.u. per Lb.	Theoret. Vel. Ft. per Sec.	Calcul. Vel. Ft. per Sec.	Eff. %
9	100	0.638	385	....	....	....	....	....	96.1
	115	0.735	442	....	....	....	....	....	96.3
	130	0.832	498	....	....	....	....	....	96.0
	145	0.929	553	....	....	....	....	....	95.5
11	100	0.638	385	12.45	311.5	280.1	3948	3744	89.9
	115	0.735	442	14.351	313.6	282.4	3962	3759	90.0
	130	0.832	498	16.244	315.4	285.0	3973	3776	90.4
	145	0.929	553	18.134	317.4	288.0	3985	3796	90.7
13	100	1.116	389	....	....	....	....	....	98.3
	115	1.288	446	....	....	....	....	....	97.9
	130	1.46	502	....	....	....	....	....	97.5
	145	1.632	558	....	....	....	....	....	97.1
14	100	1.116	389	12.295	284.7	267.6	3774	3659	94.0
	115	1.288	446	14.147	286.5	269.5	3796	3672	94.1
	130	1.46	502	15.977	288.2	271.3	3798	3685	94.2
	145	1.632	558	17.821	289.8	273.2	3808	3698	94.3

TABLE 6 EFFECT OF ERROR IN OBSERVATIONS

Nozzle No.	Error in Observation		Corresponding % Error in Efficiency	
	+	−	+	−
9	0.1 lb. per sq. in.	Terminal Pressure		8.5 to 14.0
11	0.1 lb. per sq. in.	Terminal Pressure		0.03 to 0.3
13	0.1 lb. per sq. in.	Terminal Pressure		5.4 to 9.2
14	0.1 lb. per sq. in.	Terminal Pressure		0.02 to 0.07
9	5 lb. per hr.	Flow	1.0 to 1.6	
11	5 lb. per hr.	Flow		1.6 to 2.4
13	5 lb. per hr.	Flow	1.1 to 1.5	
14	5 lb. per hr.	Flow		1.67 to 2.46
9	2%	Dryness Factor	0.9 to 0.6	
11	2%	Dryness Factor		1.6
13	2%	Dryness Factor	0.9 to 0.7	
14	2%	Dryness Factor		1.7
11	0.1 lb.	Reaction	1.0 to 1.45	
14	0.1 lb	Reaction		1.05 to 1.54

Note.—An error of +0.1 lb. would be caused in the calculated reaction by an error of +0.1 lb. per sq. in. in the box pressure-reading of No. 14 or by an error of + 0.0628 lb. per sq. in. in the box pressure-reading of No. 11.

RESULTS AND CONCLUSIONS

47 Table 5 gives a summary of the calculations for nozzles No. 9, 11, 13 and 14, and Table 6 a summary showing what would be the effect of error in the observed values. The discrepancy between the efficiencies calculated for the search-tube and the reaction nozzles is principally due to the great difference in the effect on the two methods of calculation of a small error in terminal pressure. An increase of only $\frac{1}{20}$ lb. per sq. in. over the value used would cover the discrepancy. Corrections for any slight condenser leak which may have existed would decrease the flow values and bring the calculated efficiencies closer together.

48 The terminal pressures chosen were the minimum observed values. The dryness factor was assumed as 100 per cent. Assuming a 2 per cent moisture would make the calculated efficiencies for No. 13 and No. 14 very nearly equal, and very materially reduce the difference between No. 9 and No. 11.

49 In consideration of the above, taken in connection with Tables 2 and 3, we may assume that the values 91.5 per cent for No. 9 and No. 11, and 95 per cent for No. 13 and No. 14, are probably within 2 per cent of the true efficiencies. No. 15 and No. 16 show a trifle less reaction than No. 14 but the flow also appears to be a trifle less, and there is not sufficient ground for assuming any difference between the efficiencies of these three nozzles. Neither is there any appreciable difference in Nos. 10, 11 and 12. No. 18, with a greater flow and less reaction than No. 11, shows an efficiency of about three per cent less. Since no appreciable difference in efficiency is shown either with a variation in cone angle from 9 deg. to 20 deg., or with the variations in contour shown in nozzles No. 15 and No. 16, smoothness of finish would appear to be a much more important factor than contour.

GOVERNING ROLLING MILL ENGINES

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Associate Member of the Society

In considering the conservation of steam-power equipment for driving rolling mills, we must take into account the two methods of rolling: the two-high mill driven by a reversing engine, and the three-high mill driven continuously in one direction; and the relative amount of power required for each.

2 There is very little variation in the type used for each class of mill. Twin engines are used for two-high mills and single engines for three-high mills, usually tandem compounds.

3 The reversing engine for the two-high mill must be powerful enough to take care of the engine and mill friction and the maximum torque produced by the piece in the rolls in any position. As these engines are usually twin engines with cranks at 90 deg., each side must be capable of doing the work alone when the other side is on the dead center.

4 In determining the size and distribution of the metal in engines of this type it is the custom to make the dimensions a little larger and the parts a little heavier than have been used before for the same work. Reciprocating parts are made heavier to stand the shocks, thereby increasing their inertia, and making necessary heavier frames, bedplates, bearings and pins, as well as more rigid adjustments, which in turn require more attention.

5 As an example of the power sometimes used for an engine of this type, a certain engine may be cited which was fully capable of delivering 25,000 h.p. while the actual average work on the steel passing through the mill could not have required more than 2000 h.p. at the maximum capacity of the mill. The engine and mill friction, if the mill were driven continually in one direction, would not fall much short of 1000 h.p. Assuming that each reversal would absorb 50 h.p., and that there were ten reversals per minute, 500 h.p. would be con-

All papers are subject to revision.

sumed in this way. The total average work of the engine was thus about 3500 h.p., only one-seventh of its capacity.

6 As the three-high mill is driven continually in one direction, the energy stored in the flywheel makes it possible to do the same work with considerably less than one-half the maximum power required in the former case, the amount depending upon the size and weight of the flywheel. The greater the amount of energy the wheel can store up, the closer can the maximum power required approach the average work of the mill, resulting in the more economical use of steam and a lower cost of equipment.

7 Mill designers do not always give sufficient consideration to this fact and operators have to deal later with high steam cost and difficulty in keeping the proper steam pressure. Of course, there are other features to be considered, but economical use of power is a very important item.

8 For driving a three-high mill a twin engine of the cross-compound type could be used with an intercepting valve such as is employed in locomotive practice, by which the engine could be started from any position and handled by a quick-acting throttle valve, so that it could be brought to a standstill as soon as a piece passed through the rolls, if another were not ready to enter the mill. Such an arrangement would go a long way toward answering one of the principal arguments in favor of the two-high mill: that its engine uses steam only when the piece is on the mill.

9 If an engine of the type described be furnished with a very heavy flywheel located between the engine and the mill, the shocks due to the piece striking the rolls will be taken very largely by the flywheel and not by the engine. Furthermore, if the engine were so designed that it could not work through the wide range of steam admission, as is the current practice, the abnormal amount of compression now necessary would be cut down to a large extent, the parts of the engine would be strained less, and the engine would run with greater steam economy owing to the cutting out of the high release pressure during heavy work and the reduction of the number of strokes during the period of negative work.

10 Going into the details of operation of an engine driving a three-high mill, we find:

a That the engine first develops just enough power to take care of the friction of engine and mill.

11 If the engine were running at a constant speed during this

period, just enough steam would be admitted to the cylinder at each revolution to do the work with the least possible variation of cut-off, resulting in the most economical use of the steam. The more the speed varies the greater the amount of steam required per horsepower developed.

12 A constant speed is also desirable for another reason; namely, the available energy stored in the flywheel is always normal under these conditions, whereas with a varying speed it would be below the normal about one-half the time. Should the piece strike the rolls when the steam pressure is low and the steel cold, the engine would be more liable to stall if the stored energy were below normal than if it remained constant.

b Next, the piece strikes the rolls.

13 The initial force of this blow is absorbed by the flywheel and the speed of the engine is reduced in consequence. When this has dropped, say four or five revolutions, the governor has probably so adjusted the steam valves that the engine is developing its maximum power and the valves will remain in this adjustment until the engine is nearly up to speed again. During this time the release pressure will be high, making it necessary to carry a very high compression, conditions under which a non-condensing engine will make the most noise. Further, if the steam going to waste were utilized the engine would be capable of doing about one-third more work.

c Next, the piece leaves the rolls.

14 On many passes the engine is receiving the maximum amount of steam at this instant and the flywheel absorbs energy through the increase of speed above normal. In the writer's opinion, this is the time when nearly all of the failures of flywheels on rolling mill engines occur, and anything that can be done to cut down the amount of energy to be absorbed by the wheel at this time will increase the safety of the engine and decrease the repairs on the engine and mill.

15 Having in most cases reached the highest point of speed, the governor will shut off steam entirely from the cylinder, the engine will slow down to several revolutions below normal speed before sufficient steam will be admitted to increase this speed again and the result will be a wide range of the speed variation during the first period when the engine has simply to overcome its own friction and that of the mill.

16 The operations outlined in the foregoing are very complicated when two or more passes occur at the same time.

17 The results of a study of the above details of operation of the No. 1 rail mill engine driving the four-pass roughing rolls at the Ensley Rail Mill of the Tennessee Coal Iron and Railroad Company, during a series of tests show how great a difference in the performance of the engine the writer was able to obtain with one adjusting screw added to the governor.

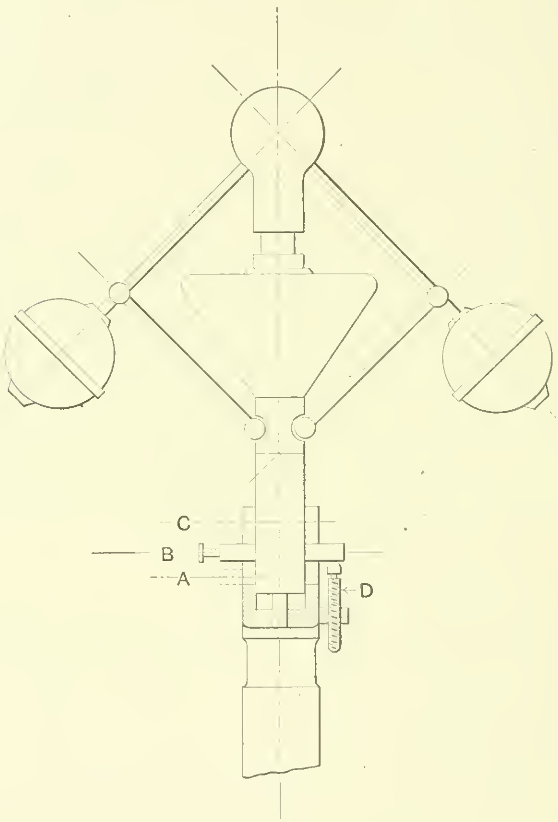

Fig. 1 Showing Location and Function of the Adjusting Screw *D* on the Governor

18 The engine is a Reynolds Corliss, 52 in. by 72 in., non-condensing, equipped with a long-range cut-off valve gear.

19 Fig. 1 shows the location of the adjusting screw *D* on the governor. Its purpose is to prevent the governor from dropping to position *A* which would allow the maximum amount of steam to

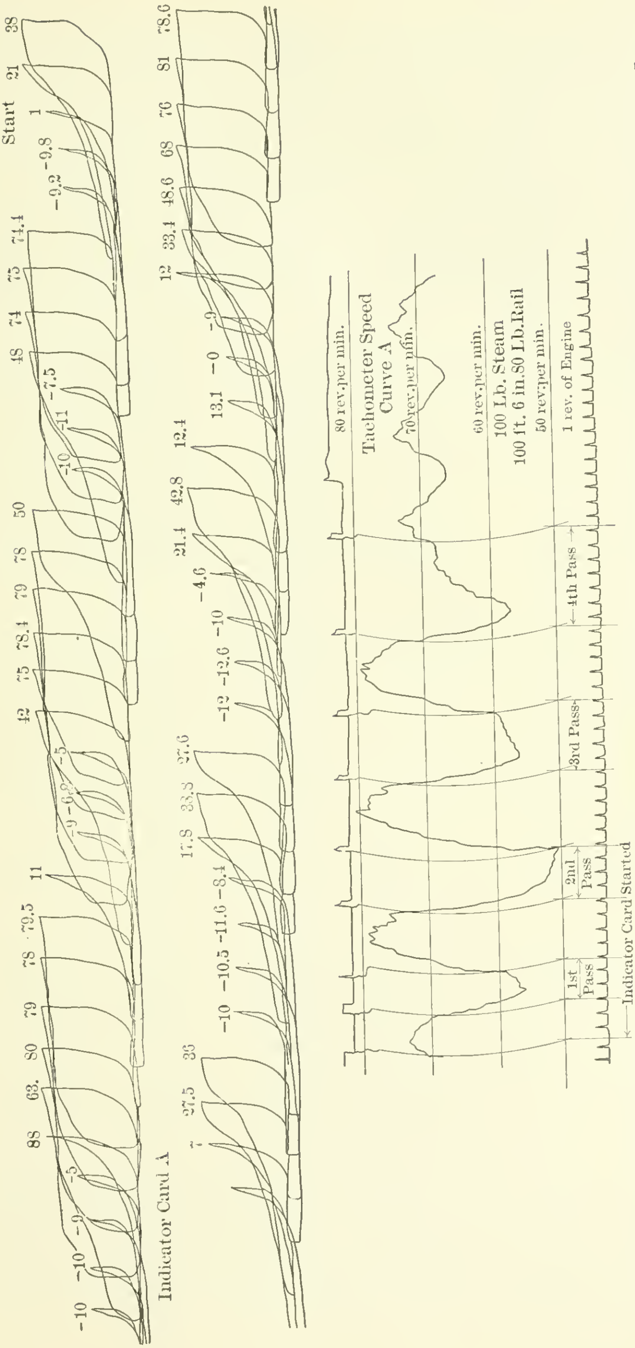

FIG. 2 CONTINUOUS INDICATOR CARD A AND TACHOMETER SPEED CURVE A OF NO. 1 RAIL MILL ENGINE, 52 IN. BY 72 IN.

THE CARD AND CURVE WERE TAKEN AT THE SAME TIME AND SHOW ORDINARY PERFORMANCE. THE LOWER HALF OF INDICATOR CARD IS A CONTINUATION OF THE UPPER HALF

reach the cylinder, as determined by the valve gear. In this case the steam was admitted nearly three-quarters of the stroke with the governor in this position. When the pin is in position *C* the steam is entirely cut off. The screw *D* was adjusted very slowly while the engine was under load to determine the most advisable position *B*.

20 This position must be at a point such that the engine will carry an average load and also will not stop under a heavy load. It can readily be seen that by reducing the range of adjustment of steam distribution the engine will operate with more economical steam consumption and the greatest strains on the engine and mill will be reduced.

21 The degree of success attained by this adjustment may be judged somewhat by the accompanying continuous indicator cards and tachometer speed curves. Card and curve marked *A* (Fig. 2) were taken together before the attachment was used. Card and curve *B* (Fig. 3) were taken when the attachment was in use.

22 The speed curves were made by a recording tachometer which the writer rigged up from a Schaeffer & Budenberg indicating tachometer.

23 This indicating instrument was mounted on a plate, a bevel gear being fastened to the end of its driving shaft, which in turn drives a shaft with a worm at one end. The worm shaft is mounted on a bracket which will swing out of gear, thus disconnecting the indicating instrument if desirable. The worm wheel driven by the worm shaft runs loose on one of the paper-feed rolls and when a record is to be taken a small clutch causes the worm wheel to drive the rolls. Two rolls are geared together and a third acts as a press roll. The paper rolls used were such as are furnished for the Uehling pneumatic pyrometer.

24 The indicating needle on the original tachometer was replaced by a longer one which reached to the paper. A pencil was attached to the end of the new needle but there was so much friction that the records were of no value, so a small tin funnel was fastened to the needle and a linen thread passed through the hole in the bottom, protruding about $\frac{1}{8}$ in. The ink in the funnel worked down the thread to the paper and made a satisfactory record.

25 Below the paper-supporting plate is a vertical plate to which are fastened two electric bells with the gongs removed and pencils substituted for the clappers. One of these bells was operated by a contact made once in a revolution of the engine, the record being shown at the bottom of the curve *A* (Fig. 2.) As it was very evident

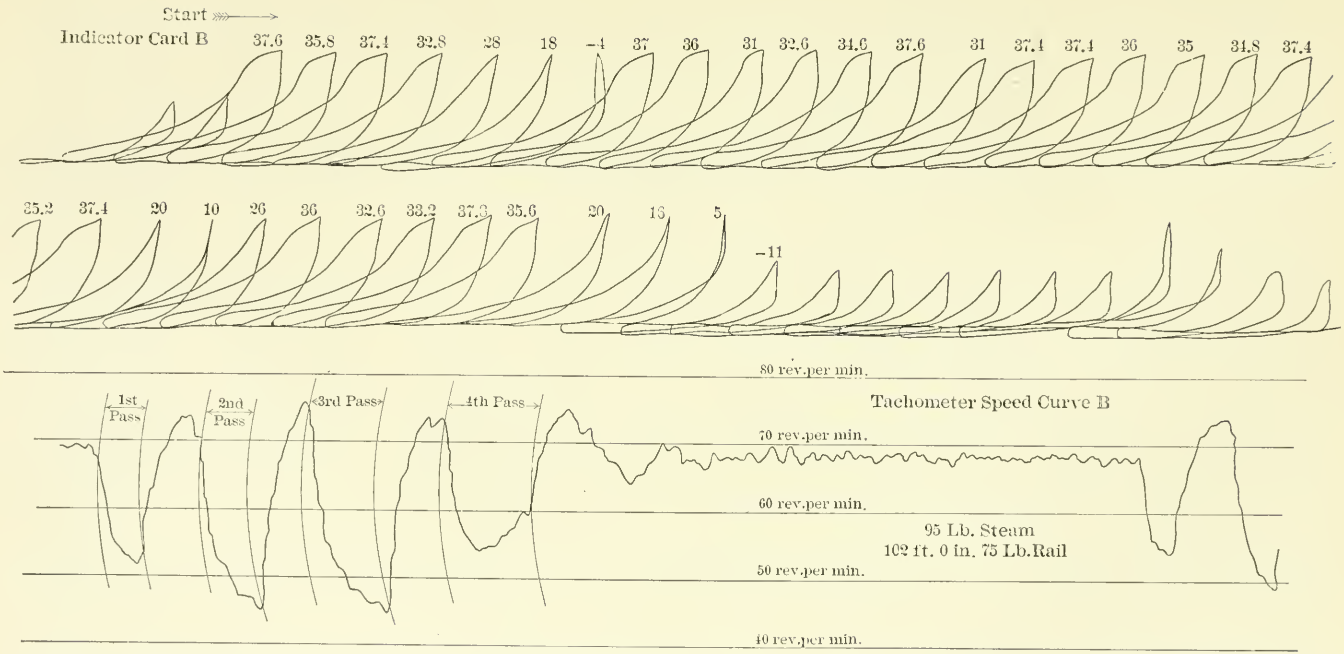

FIG. 3 CONTINUOUS INDICATOR CARD *B* AND TACHOMETER SPEED CURVE *B* TAKEN WHEN RUNNING WITH THE CAINE METHOD OF ENGINE CONTROL

THE LOWER HALF OF THE INDICATOR CARD IS A CONTINUATION OF THE UPPER HALF

that the paper would always feed the same amount at each revolution it was not considered necessary to use this device each time.

26 The other bell was operated on a circuit that had two gaps in series, one of which was closed when the indicator cards were started and the other kept closed except at the instant an observer at the rolls indicated the start and stop of the various passes, by momentarily breaking the circuit by means of a push button. This last feature also appears unnecessary, as the speed curves have a pronounced change of direction at these instants.

27 From card *A* it will be noted that during the four passes there are 37 records showing that the engine is taking steam, and 22 records showing that it is not. These would lead one to think that if every card were a positive one, and the work were distributed throughout the entire period between pieces, and the mean effective pressure averaged, there would be a more economical use of steam, and possibly with a heavy flywheel the size of cylinder could be reduced. That would be the ideal condition, which cannot be realized, however, because of three changing functions: the varying time between pieces, the varying temperature of the steel and the varying steam pressure.

28 Card *B*, Fig. 3, shows the engine doing the same work as before, on a piece of the same length, and it can be seen that the work is distributed over 34 revolutions and only two negative cards. With the engine running as this card shows, it is a comparatively easy proposition to set the valves for economical steam distribution and it is also much easier to keep the rods and boxes properly adjusted. The low terminal pressure is the cause of the engine's running much more quietly than when card *A* was taken.

29 The indicated steam consumption of card *A* is about 43 lb. of steam per h.p. per hr., against 37 lb. in card *B*, a saving during rolling periods of over 20 per cent.

30 Of the speed curves, curve *A* shows that during the friction load the engine varies from 66 to 73 r.p.m., with an average of about 69 revolutions, and after the passes the speed becomes about 80 r.p.m., an increase of 11 revolutions above normal. Curve *A* shows also that the second pass is the heaviest one of the four, the speed dropping to 51 r.p.m.

31 Curve *B* indicates that during friction load the speed varies only about 3 r.p.m., and that the highest velocity is 75 r.p.m., or 7 above normal. Some changes were made on the rolls between the two records so that the third pass was as heavy as the second and the speed drops to about 45 r.p.m. These curves indicate that the engine

TABLE OF DATA FOR SUCCESSIVE PASSES

No. 1 Rail Mill Engine, E. P. Allis, 52 in. × 72 in. 4 Roughing Passes, Rolls $27\frac{3}{8}$ in. Pitch Diameter, Product 100 ft. 6 in., 80-lb. Rail, Total Weight, 2680 lb.

		First Pass	Intervals	Second Pass	Intervals	Third Pass	Intervals	Fourth Pass	Intervals	Total
1	Area section after pass, sq. in.	54		33.5		22.9		19		
2	Length section after pass	15.95		25.7		37.6		45.2		
3	Revolutions	2.23	4.77	3.59	5.41	5.25	5.25	6.31	4.19	37
4	Speed at start } from curve	70.0	58	76	51	76.5	59	74	68	
5	Speed at finish } from curve	58.0	76	51	76.5	59.0	74	68	69	
6	Total m.e.p., pass and intervals	461.7		702.6		719.5		677.2		
7	Total energy pass and intervals, ft. lbs.*	5,755,000		8 758,000		8,968,000		8,440,000		
8	Total energy, ft. lbs.*	2,602,200	3,152,800	4,573,500	4,184,500	6,276,300	2,691,700	8,008,800	431,200	
9	Energy taken from flywheel, 1180 $(n^2_1 - n^2_2)$	1,812,500		3,747,000		2,798,000		1,005,000		
10	Energy added to flywheel		2,846,000		3,836,500		2,354,000		161,700	
11	Energy, total	4,414,700		8,320,500		9,074,300		9,013,800		
12	Energy in friction, 64,320 ft. lb. per rev.	143,400	306,800	230,900	348,000	337,700	337,700	406,000	269,500	2,380,000
13	Energy, total, less friction in piece	4,271,300		8,089,600		8,736,600		8,607,800		29,705,300
14	Torque per foot length of piece	268,000		315,000		232,000		191,000		

*From cylinders 12,464 × m.e.p

could be speeded up to about 75 r.p.m. and not exceed the speeds used before, that more energy was stored in the flywheel and that the engine would not drop below the speed shown on Curve *A*.

32 Referring to the table, the constant used in items 7 and 8 is the foot-pounds of work for one stroke of the engine at 1 lb. mean effective pressure.

33 In the original calculation for item 9 only the flywheel was considered. This is 22 ft. in diameter, weighs about 130,000 lb. and has a radius of gyration of about 7.4 ft. Taking the formula

$$\text{energy} = \frac{Wv^2}{2g}$$

and altering it to get the energy stored up or given out at a change in velocity of one revolution per minute it becomes

$$E \text{ for 1 r.p.m.} = \frac{\text{wt. wheel}\left(\dfrac{\text{radius gyration} \times 2\pi}{60 \text{ seconds}}\right)^2}{64.32}$$

Substituting and solving with the values given above

$$E \text{ for 1 r.p.m.} = 1220 \text{ ft.-lb.}$$

As the energy varies as the square of the velocity we would use the following to represent the amount of energy involved in a change of velocity

$$E = 1220\ n_1^2 - n_2^2$$

in which n_1 is the higher number of revolutions of the engine and n_2 the lower number. In checking this up against indicator card and speed curve results on friction alone, it became evident that 1180 was the proper constant to use to include the inertia effects of the mill and reciprocating parts.

34 The constant in item 12 was the average foot-pounds of work per revolution during the friction period as calculated from the indicator cards. The slide rule was used in making the calculations.

COOLING TOWERS FOR STEAM AND GAS-POWER PLANTS

WITH PARTICULAR REFERENCE TO THE POSSIBILITIES OF THE NATURAL-DRAFT AND AUXILIARY-DRAFT TYPE

By J. R. Bibbins, New York

Member of the Society

The object of this paper is to bring to the attention of the members of the Society a subject which has received relatively little attention in the past, but which the author believes merits the careful study of all engineers interested in future power-plant development. The cooling tower has been looked upon as a makeshift, and its use has been correspondingly restricted. This, however, is largely due to the extremely limited information of an exact or technical nature, relative to the possible performance under unfavorable weather conditions, available to the general public, as well as to the somewhat uncertain factor of depreciation. And, further, it is the author's belief that the present high prices[1] constitute the greatest obstacle to the more widespread adoption of the cooling tower in both turbine and gas-power plants.

2 Believing that interest may be aroused in this subject by a more widespread dissemination of engineering data, the author will present for discussion a type of tower with which some personal experience has been acquired, and suggest a type of combined fan and natural draft which would be suited to most efficient running on peak as well as light loads. It is not the intention to discredit the cooling tower in its present forms but rather to bring about a more general recognition of its inherent advantages.

[1] Some recent quotations from a number of builders of forced-draft towers suitable for a load of several thousand kilowatts, (*not including* the motor or engine for driving the fan), ranged between $4.80 and $6.93 per kw., as much as the entire condensing equipment.

PRESENT FIELD

3 There is a continual demand for cooling towers from inland power stations where the condensing water supply is costly or restricted. Turbine-driven plants, as a rule, operate with higher vacuum than those engine-driven, with the result that the perform-

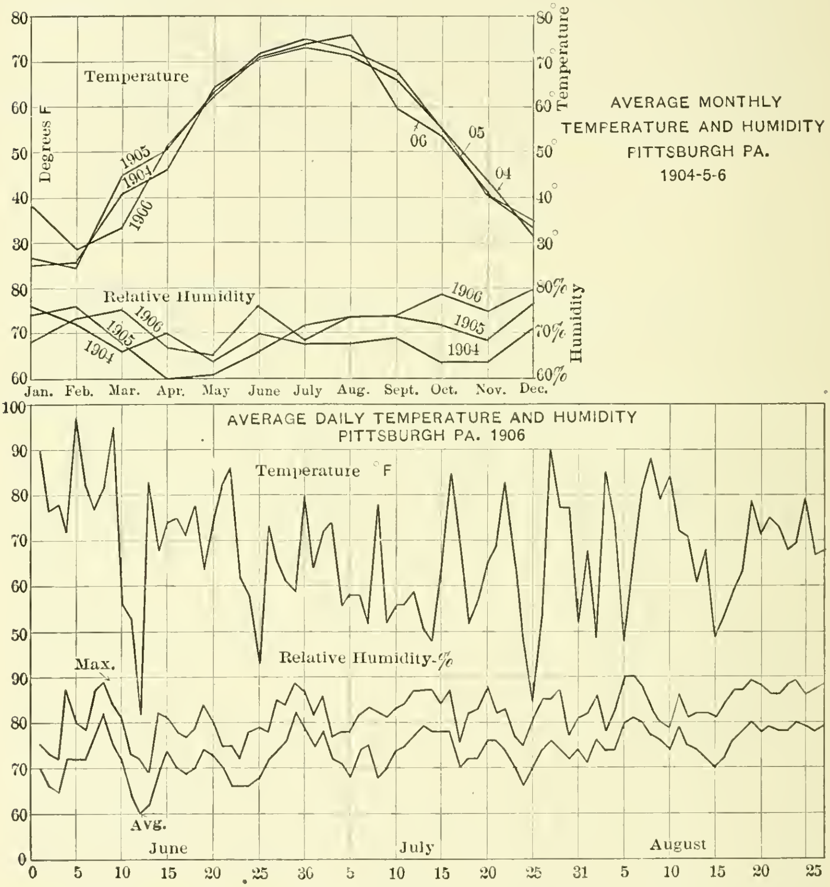

FIG. 1 CYCLES OF AVERAGE TEMPERATURE AND HUMIDITY AT PITTSBURGH, PA.

ance demanded of the tower must be proportionately better. In the past, cooling towers have generally been associated with badly run plants and low vacuum. This, however, is clearly a question of design and adaptation and not an inherent fault. To be sure, service requirements are not easily met (see Fig. 1). Not infrequently atmos-

pheric temperatures of 90 deg. to 100 deg. fahr. are encountered, with cooling water at 80 deg. to 90 deg. fahr. and humidity above 85 per cent saturation. Yet the auxiliary plant must be moderate in bulk and the power consumption low. Furthermore, it must be capable of overload capacity to tide over daily peak loads and periods of exces-

TABLE 1 WEATHER CONDITIONS, PITTSBURGH, PA.

DATE	AVERAGE TEMPERATURE DEGREES FAHR.	AVERAGE HUMIDITY PER CENT
1904	52.8	73
1905	52.1	68
1906	52.0	70
Average..............	52.3	70.5

Mamixum Temperature and Humidity Ranges, Summer of 1906

TEMPERATURE ABOVE	Days in Month			AVERAGE FOR MONTH
	JUNE	JULY	AUGUST	
90 deg.	..	..	2	0.6
85	6	9	14	10.5
80	8	14	10	20.5
75	10	6	4	27.7
70	5	2	1	23.7
Below	..	..	..	..

HUMIDITY ABOVE	Days in Month			AVERAGE FOR MONTH
	JUNE	JULY	AUGUST	
90 %	3	1	3	2.3
80	14	10	15	13.0
70	8	11	11	10.0
60	3	8	2	4.3
50	2	1	..	1.0
Below	..	..	..	..

Data from Pittsburgh Weather Bureau.

sively hot and humid weather, and all of this with small investment cost.

4 Curiously enough, there is an active demand for cooling towers in the South, e. g., Florida, where the atmospheric conditions are the most unsuitable; also in the Western mining and coast regions. For-

tunately, low humidity prevails here, as a general rule (e. g., Colorado Springs ranges around 50 per cent).

5 In power-gas work, the demand for cooling towers is especially pressing. The large quantity of water required for engine jackets and for gas cooling and washing, entails a heavy expense if water is scarce and costly. Gas-engine discharge water, being quite pure, should not be wasted, but cooled and returned to the plant. Even with deep well pumps supplying sufficient water for cooling, a station

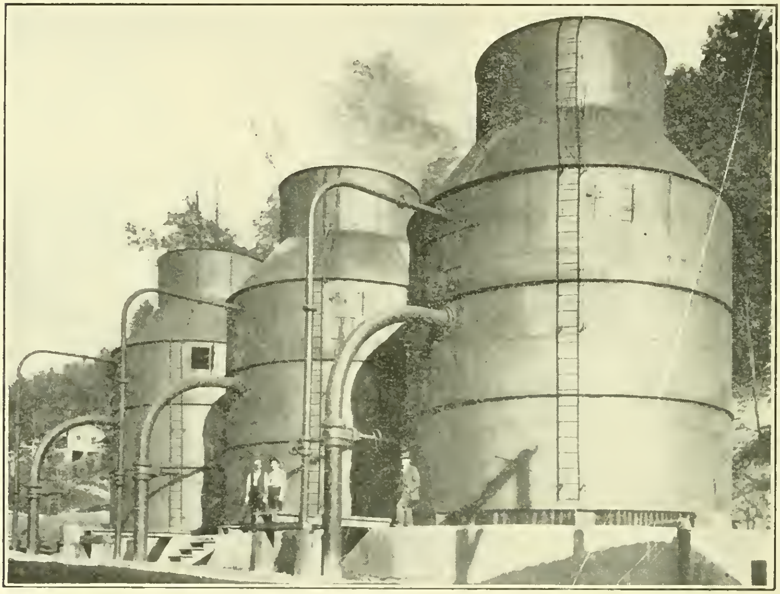

Fig. 2 4500-h.p. Natural-Forced-Draft Cooling Tower at Gary, W. Va., for a Low-Pressure and High-Pressure Turbine Installation

These towers have auxiliary fans in the stack driven by Pelton wheels and small turbine-driven rotary pumps located in the power station, and operate with natural draft when not heavily loaded

is handicapped by a large expense for auxiliary power consumption. In one instance of an Arizona mining plant, the only water available for cooling was so impure as to make it necessary to install a completely *closed cooling system* for the engine jackets, in which no evaporation took place, simply cooling by conduction. In city light and power plants, not fortunate enough to be located on water frontage, cooling towers built upon the roof have been utilized for engine cool-

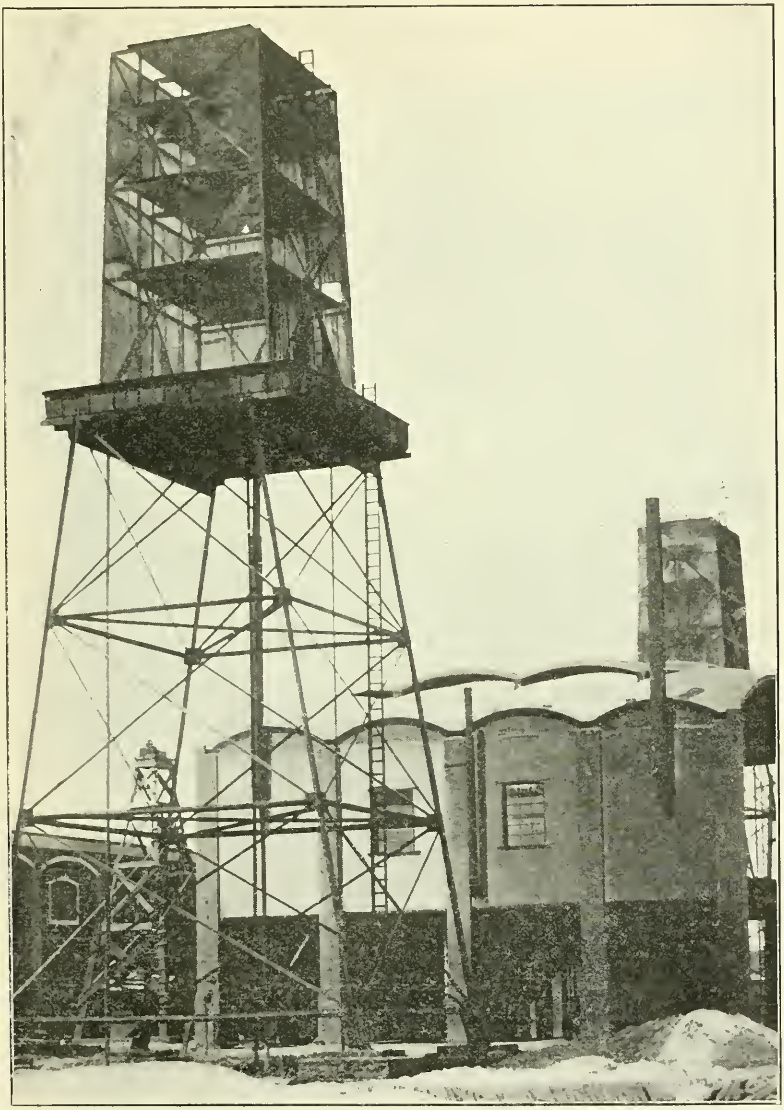

Fig. 3 1500 h.p. Open-Type Steel Tower at San Luis Potosi, Mexico, for a Gas-Power Central Station

One tower serves the engine jackets, the other the producer scrubber. The sides are encased by wire screen to reduce the water lost by windage. Cooling, 10 to 30 deg. Humidity generally low, around 50 per cent.

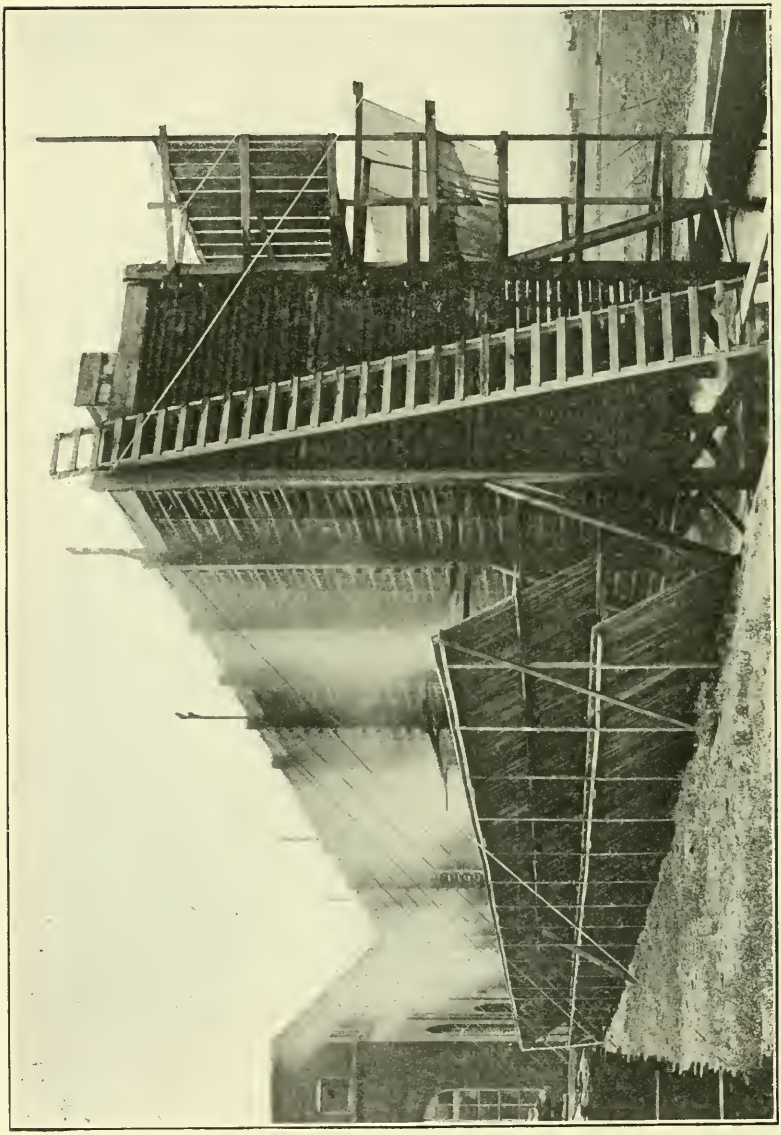

FIG. 4 2900-H.P. OPEN-TYPE WOODEN TOWER AT COLORADO SPRINGS FOR A LOW-PRESSURE TURBINE INSTALLATION WITH A LEBLANC CONDENSER

THE WIND SHIELDS REDUCE THE LOSS OF VAPOR DURING HIGH WINDS. COOLING, FROM 20 DEG. TO 30 DEG. HUMIDITY GENERALLY LOW—ABOUT 50 PER CENT.

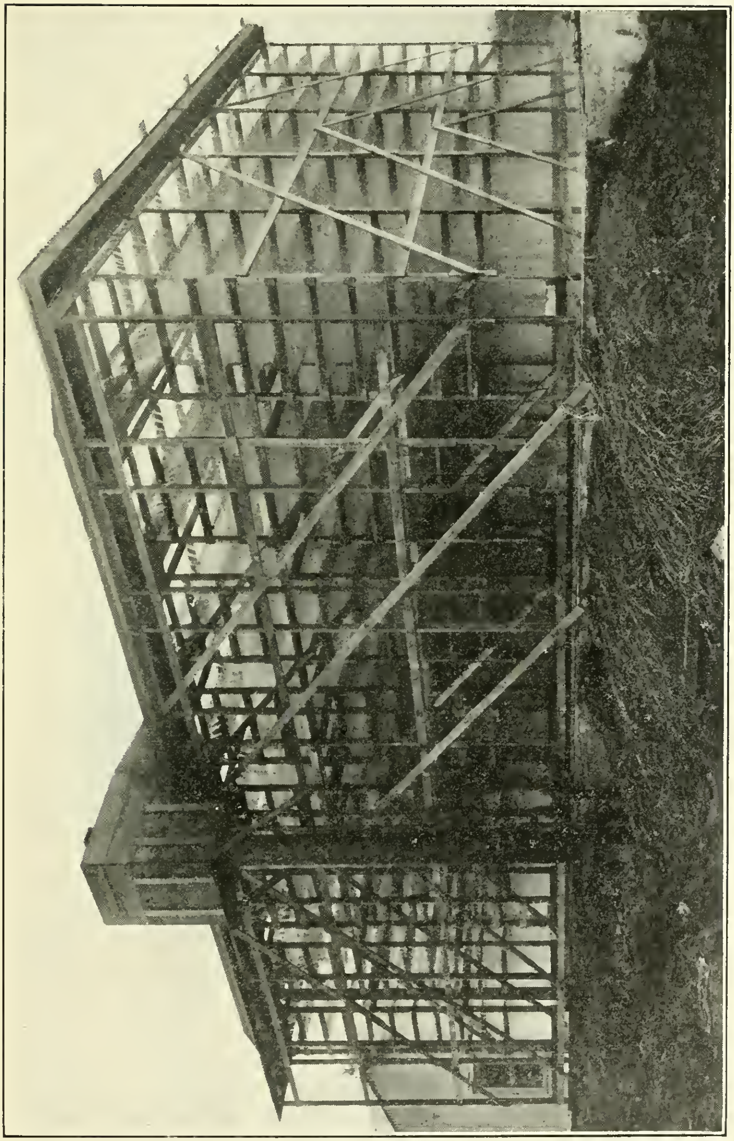

Fig. 5 2500-h.p. Open-Type Screen Tower for a Steam Turbine Plant at Visalia, Cal.

ing. The expense for buying city water for this purpose would otherwise be prohibitive except in large plants.

REPRESENTATIVE INSTALLATIONS

6 As examples of present cooling-tower practice in connection with high-grade power properties, the following may be mentioned:

a At Gary, W. Va. (Fig. 2), three towers 25 ft. in diameter by 18 ft. high serve a plant of both high and low-pressure turbines

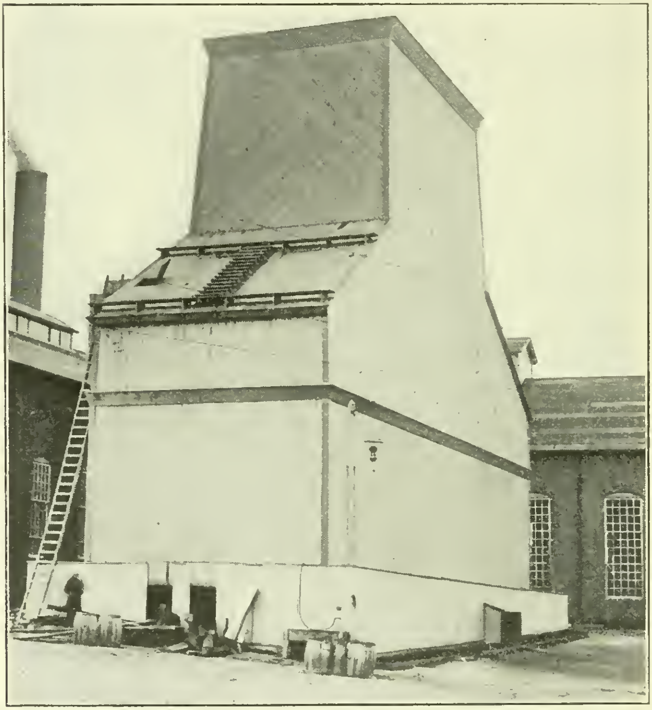

Fig. 6 5800 h.p. Natural Draft Wood Construction Tower for Steam Turbine Plant at Butte, Mont.

recently installed in connection with a non-condensing engine plant furnishing the mines with light and power. A unique feature is the induced-draft fan located in the stack and driven by a Pelton water motor, which is served in turn by a small turbine-driven centrifugal pump in the

power house. This equipment will be referred to later in connection with the combined natural-forced-draft type.

b The 13th & Mt. Vernon station of the Philadelphia Rapid Transit Company is another low-pressure turbine plant employing forced-draft cooling towers.

c At the central station at San Luis Potosi, in the Mexican highlands (Fig. 3), separate cooling towers serve engine

TABLE 2 WEATHER CONDITIONS, BUTTE, MONT.

AVERAGE TEMPERATURE AND HUMIDITY, 1894–1904 (WEATHER BUREAU, HELENA, MONT.)

MONTH	TEMPERATURE DEGREES	HUMIDITY PER CENT	MONTH	TEMPERATURE DEGREES	HUMIDITY PER CENT
January	23.7	66.8	July	62.8	45.3
February	23.9	68.6	August....	62.9	43.4
March.......	28.3	60.8	September.	52.0	53.6
April........	40.0	54.3	October ...	45.1	54.4
May.........	49.0	54.9	November.	33.7	62.7
June.........	52.0	50.0	December .	26.5	70.5
Av. for year	41.6			58.9	

TEMPERATURE RANGES

BETWEEN DEGREES	DAYS	ABOVE DEGREES	DAYS	PER CENT YEAR	HOURS	PER CENT YEAR
70– 75	25	70	99	27	276	3.15
75– 80	24	75	74	20	196	2.22
80– 85	28	80	50	13.7	158	1.8
85– 90	19	85	22	0.6	51	.58
90– 95	2	90	3	0.82	9	.097
95–100	1	95	1	0.28	1	.01
		Total	249	67	681	7.9

Data from M. H. Gerry, Jr.

and producer systems, the make-up water being furnished from deep well pumps. This plant has been in operation since 1904.

d Western plants of inexpensive construction are the Mt. Whitney Power Company (Fig. 4), and the Colorado Springs Light & Power Co. (Fig. 5), both turbine plants.

e Perhaps the best example of the adaptability of cooling towers is an equipment designed and built by the Helena

Power Transmission Company for its auxiliary turbine station at Butte, Mont. (Fig. 6).

7 This latter tower was made the subject of an exhaustive preliminary study, and subsequent test, by the company's engineering organization, and through the courtesy of M. H. Gerry, Jr., chief engineer and general manager, the writer has been able to place the complete report at the disposal of the Society for future consideration. The tower (shown in Fig. 6) serves a turbine plant of 4000-kw. capacity at 28-in. vacuum. The designers state that after two years' experience the results coincide closely with the theoretical deductions made before its construction.

SPECIAL PHASES OF COOLING TOWER OPERATION

8 Two important factors fortunately contribute to the effective operation of a cooling tower:

a One factor is the well-known characteristic of a natural-draft tower considered as a "chimney"—increase in capacity with increase in temperature head (see Fig. 12).

9 In steam work, especially with high vacuum, the general range of condenser-discharge temperatures is relatively low; in gas work, on the other hand, it is high. Pistons are today operated at temperatures of 140 deg. to 160 deg., cylinders from 120 deg. to 150 deg., occasionally higher. Owing to the small volume of water in the minor circuits, such as valves, packings, etc., these temperatures have little effect upon the average outlet temperature of the engine, which ranges from 115 deg. to 130 deg. in the large engines, and 140 deg. in the smaller sizes and verticals. This would correspond to a very poor vacuum in a steam plant, not more than 24 in. to 26 in.; practically out of the question in turbine work. However, this high temperature results in a high rate of heat dissipation in the tower per unit of cooling surface, with a corresponding reduction in bulk of tower.

b The second factor relates to developments in the efficiency of the steam-condensing plant.

10 The function of a condenser is, primarily, that of a water heater and the measure of its efficiency as a condensing vessel is the difference between the temperature of the exhaust steam and that of the discharge water. A theoretically perfect condenser would heat the outgoing cooling water exactly to the temperature of the incoming steam. But in practice from 10 deg. to 50 deg. difference exists,

depending upon the type of condenser and the volumetric ratio of water to steam. A good surface condensing plant with dry-air pump should operate at 28-in. vacuum with a temperature difference of 15 deg.; often it is more, and the author has seen 25 deg. to 40 deg. difference in some of the largest stations in the country. A good barometric or centrifugal jet condenser, with dry-air pump, should operate with a temperature-difference of 10 deg. to 15 deg. Although it is possible for this type to operate on less—perhaps 5 deg. to 10 deg.—commercial practice rarely concedes such results.

11 A very recent development in air pumps has made it possible to operate on still smaller difference, from 2 deg. to 5 deg., with a

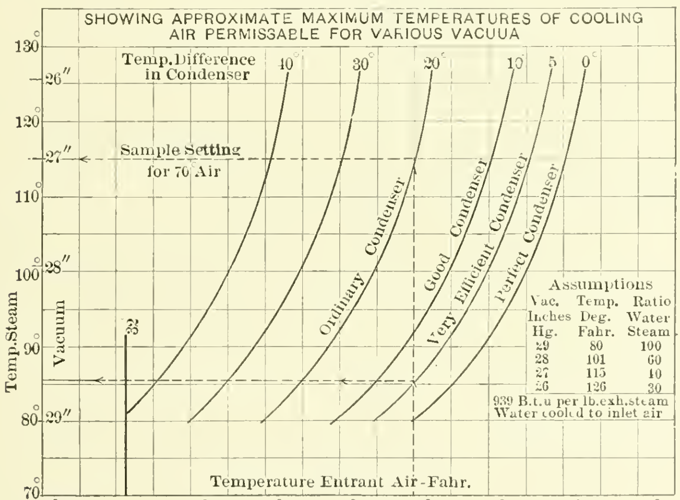

Fig. 7 Showing Maximum Air-Inlet Temperatures for Various Vacuums

reasonable water ratio, and even to approximate theoretical conditions. All this is in the right direction. The smaller this temperature differential, the higher the maximum inlet temperatures permissible for a given set of conditions—both water to condenser and air to tower. The curves in Fig. 7 show this relation in approximate form—vacuum possible with varying condenser and fixed cooling tower performance. For example, with 28-in. vacuum, 20 deg. differential in the condenser, water ratio 60, and 15 deg. cooling in the tower, the highest possible temperatureof out side air would be 65 deg. Fahr. With warmer air, the vacuum would necessarily fall.

Under the same conditions, with 10 deg. differential, a maximum air temperature of 76 deg. would be permissible; and with 5 deg., 81 deg. inlet air. It is therefore apparent that the tendency of modern condenser development toward higher efficiencies will materially assist in the successful operation of cooling towers under extremely adverse conditions.

ELEMENTS OF DESIGN

12 The most important elements entering into the design may be considered under the following heads; having special reference to the enclosed type of cooling tower, which for a given floor space has by far the greatest cooling capacity:

a Type of cooling surface,

b Water distribution system.

c Draft and air distribution.

13 Following are a number of essential points that seem to the writer to have a most important bearing upon any type of tower designed for maximum duty and efficiency.

a All tortuous or unduly obstructed passages should be avoided. It is of no advantage to give ample spacing in one part of the tower and contract it in another, unless sufficient stack height is provided to overcome the additional resistance.

b Avoid free falling water. It should be distributed so as to descend clinging to some form of wetted surface.

c Avoid open spaces in the mat work, usually occurring at points where it is difficult to fill in between the frame of the tower. This will "short-circuit" and invariably diminish the effectiveness of the working sections.

d Reduce working section to minimum possible height, adding extra stack if necessary. The power required to elevate the water is important, and the working height of the tower is lost, even in a closed-condenser circulating system.

e Baffles or variable spacing are often necessary to obtain uniform air distribution.

f A settling basin of liberal depth is always advisable in order that entrained air may separate. In all jet-condenser installations, this is extremely important owing to the amount of air returned to the condenser; and even in

surface installations, this air will find its way back to the condenser via the feed water: result, impaired vacuum.

g All wooden mat surface is subject to swelling. Means should be taken to insure permanent alignment; otherwise serious reduction in draft area and capacity may be encountered.

h For maximum effectiveness, a cooling surface is required which provides uninterrupted descent of water, in a thin film at all times in intimate contact with ascending air. If any interruption is necessary, the descending sheet should be guided into place to avoid free fall.

PRESENT TYPES

14 The various types of cooling systems now in use naturally group themselves into a few general classes:

a The simple spiral-spray nozzle discharging into an open pond.

15 A prominent example is the 10,000-kw. Wyoming Ave. turbine station of the Philadelphia Rapid Transit Company, where this cooling pond is employed during a portion of the summer months. It has been suggested that the sprays be mounted upon the power-station roof, thereby taking advantage of the inclined surface of the roof for extra cooling effect, suitable gutters returning the water to the cold well. There might be some hesitancy about installing a reservoir on the roof; but in one notable instance, the recently designed gas-power station of the Duquesne Lighting Company, Pittsburg, Pa., the roof reservoir forms a very effective part of the cooling system. Here a small cascade type of tower assists in cooling. Without other agency this simple system requires only 10 to 20 per cent make-up water.

b The simple tray type, Fig. 3, with water dripping through perforations, and cooling entirely by means of transverse air currents from the side.

16 Here no direct draft is possible, and the tower has no direct cooling surface. The trays operate simply to arrest the fall of the water. In this respect, the type is a simple mechanical refinement of a rough frame tower filled with brush, such as has often been employed in temporary power work. It is, however, comparatively inexpensive, and under some conditions, may be utilized to advantage. The tower of the Potosina Electric Company, San Luis Potosi, Mexico, is built entirely of structural materials and cools from 10 deg.

to 30 deg. with very low humidities. Although encased in netting to prevent loss by spraying, as much as 10 per cent of the volume passing through the tower is carried away during a brisk wind. The inexpensive construction is shown in Fig. 5, using horizontal wire screens instead of perforated trays and without wind screens.

c The simple cascade type, constructed either of wood or of corrugated sheet, in which a considerable part of the cooling is by actual conduction.

17 In the case of the original gas engine service plant of the Union Switch & Signal Co., Swissdale, Pa., this cascade system materially assisted in the work of cooling the gas engine jacket water, but the abstraction of heat through the concrete walls of a large reservoir was largely responsible for the cooling. This cascade system seems to have been overrated. In one prominent plant, the author understands it to have been a decided failure; in any form, it is extremely primitive and not in accordance with effective design.

d Another representative of the simple types of construction is the multiple cascade. (See Fig. 8.)

18 Here the fall of water is simply interrupted at short intervals, and no cooling surface is installed. It is evident that successful operation is dependent entirely upon the accuracy with which the trajectory of the falling particles can be predetermined in the spacing of trays and maintained in the subsequent operation of the tower. This would require an absolutely constant head.

19 The tower at Colorado Springs (Fig. 4) utilizes the construction as in Fig. 8 *b*, a horizontal slotted surface with wind shields to prevent spray loss. This tower gives 40 deg. cooling in fair weather. The humidity however is very low, around 50 per cent (relative.)

e Several American towers are constructed simply of horizontal lattice work, usually of cypress, the numerous tiers being staggered in order to break more effectively the fall of water. (See Fig. 8 *c*.)

20 In some, the upper and lower faces of the lattice work are beveled to lessen the resistance of descending water and ascending air. Cooling water is distributed by atomizing nozzles, by numerous spray pipes, or by Barker's mill.[1] This type evidently does not lend itself readily to natural-draft work, owing to the serious resistance offered to the draft by the lattice work.

[1] Radial arm distributor propelled by lateral reaction of its own jets.

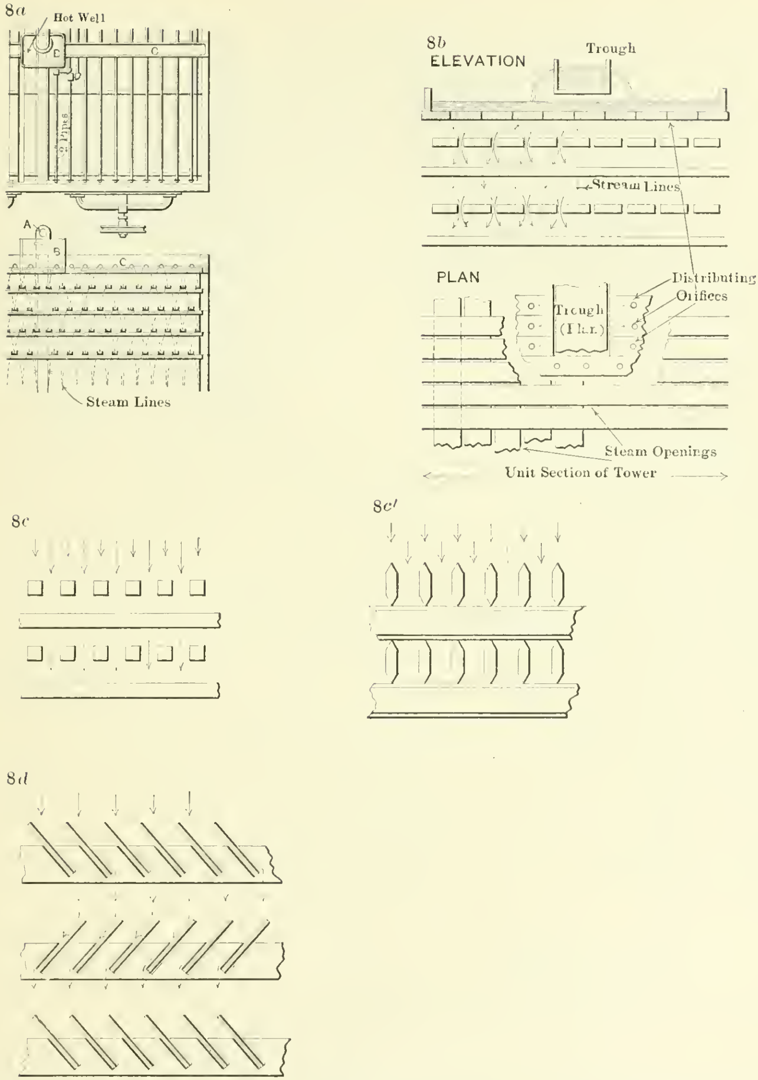

FIG. 8 *a, b, c, d* TYPES OF COOLING SURFACES EMPLOYED IN VARIOUS TOWERS

f A modification of the multiple cascade system, used in the German tower (Fig. 8 *d*), endeavors to utilize partly the inclined deflecting surface as a cooling medium, although it is a question whether this is of much effect owing to

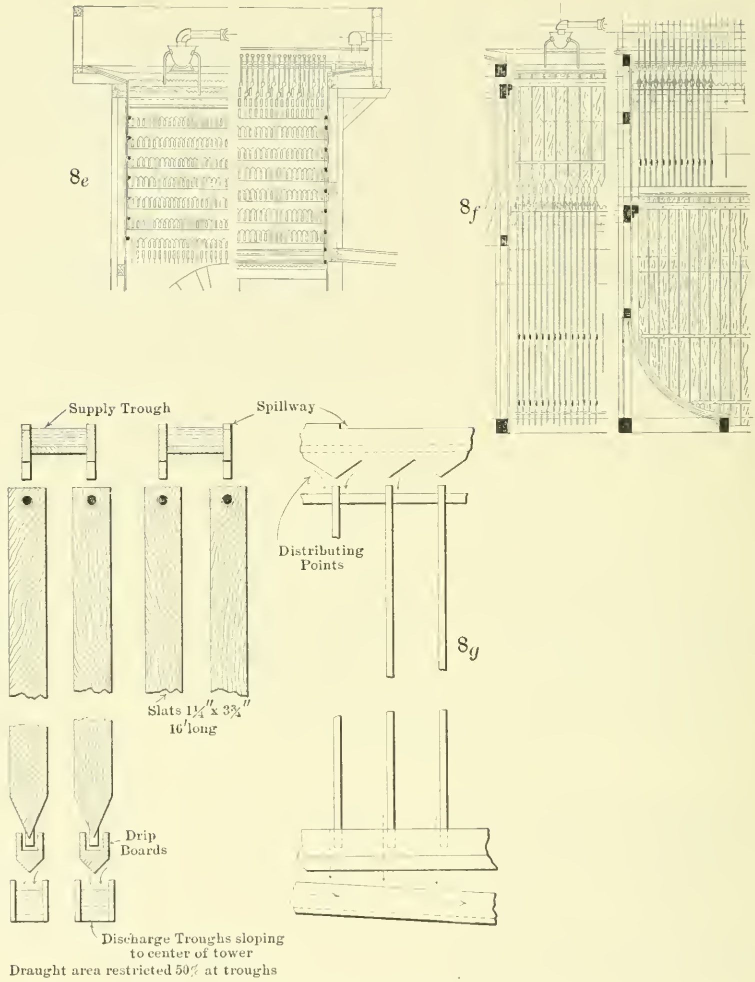

FIG. 8 *e*, *f*, *g* TYPES OF COOLING SURFACES

the fact that the ascending air in all cases impinges on the lower surface of the deflectors, and not on the upper wetted surface.

g Another German design (Fig. 8 *e*), which has been introduced into this country, advances one step in introducing vertical cooling surface in transverse tiers. But most important is the attempt to guide the water downward

in the form of a film, by forming each slat with a saw-tooth edge, meeting the lower transverse slats and guiding the water streams thereon.

21 The designer has evidently appreciated the necessity of avoiding free fall of water and deliberately piped the water from the flume to small troughs serving the upper row of slats.

22 An American builder has modified this system (Fig. 8 *k*) by practically discarding the numerous tiers of slats for vertical ones extending halfway down the tower, turning them 90 deg. at the middle of the tower, ostensibly for the purpose of equalizing air distribution. However effective this may be, we have here the desirable elements of continuously wetted surface and no free fall of water.

h A well-known American type, resembling the multiple-surface German tower (Fig. 8 *e*), employs numerous tiers of galvanized iron or tile cylinders, with a distributor at the top, of the Barker's Mill type, propelled simply by reaction of the issuing jets.

23 Although highly effective in fan-type towers, there is much free falling water owing to the non-continuity of cooling surface; and in the author's experience, there is some objection to the Barker's Mill distributor in the difficulty of maintaining ball bearings in proper condition.[1]

i Several builders employ continuous galvanized-iron surface from top to bottom of tower, either in the form of corrugated sheathing or of wire mesh, the water being carefully guided to the sheets so as to avoid free fall. The principle is right. With the close spacing permissible, a most intimate contact of air and descending film may be maintained.

j Coming now to exclusively wooden-mat construction, an example of the attempt to combine in a single slat construction all the above-mentioned desirable features, is that shown in Fig. 8 *g*.

24 This resembles the form employed by Mr. Gerry, at Butte, Mont., although it is sketched from a design by Mr. Moser, of the Newhouse Mines & Smelters Co., Newhouse, Utah. This tower is

[1] In a Detroit station, the entire condensing plant lost its vacuum on several occasions at peak load owing to the stoppage of this distributor; and, finally, a three-deck phosphor-bronze ball bearing had to be designed to withstand the corrosion from the ascending vapor.

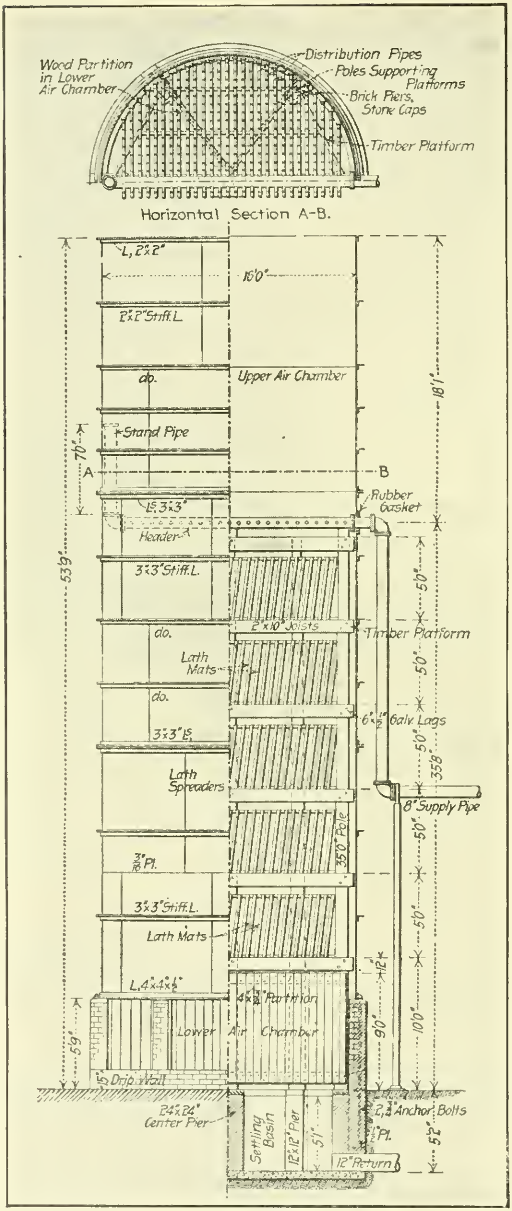

FIG. 9 EXPERIMENTAL NATURAL-DRAFT TOWER AT DETROIT, MICH.

of the natural-draft type with a side flume communicating with numerous transverse ducts which discharge upon continuous vertical slats, the saw-tooth construction being employed to guide the water on to the wetted surface. At the bottom, instead of allowing the water to fall freely into the receiving basin, each descending sheet is caught in a small trough and conveyed to the center of the tower, where it descends without retarding the ascending current of air. These distributing troughs reduce the effective draft area of the tower by about 40 per cent; but, on the other hand, the reduction in area is fairly uniform throughout the tower, and the area correspondingly diminished. That this type is extremely effective is proved by the results of the tests at Butte.

LATH MAT CONSTRUCTION

25 In a design originated in Detroit, Mich., shown in detail in Fig. 9,[1] an attempt was made to subdivide the cooling surface into sections or tiers, while maintaining the advantages of continuous vertical surface. This it was thought would facilitate the construction and repair of the tower; it was also hoped to avoid the distortion of the mat surface occasioned by the swelling[2] of the timber, which it is hard to avoid when long slats are employed.

26 This tower was designed under the direction of Alex Dow, Mem.Am.Soc.M.E., general manager of the Detroit Edison Co., largely in order to try out the natural-draft type under conditions of central station operation. There were many features which could have been improved upon, but that the type of mat surface employed was extremely effective is shown by the results of tests made in 1902.[3] The important point in design was reduced cost of construction. With the exception of the sheet-steel shell furnished by a local boiler

[1] Described in *Engineering News*, March 20, 1902.

[2] For example, this difficulty was experienced in a large gas-engine cooling tower in Texas. Plain horizontal platforms were used, with boards spaced far enough apart for the water to drip through. After some time in service, the timber had swelled to such an extent as practically to close off two-thirds of the tower, deflecting the greater portion of the water to the sides, where it descended without being cooled to any extent. This trouble, of course, is not so serious in the vertical slat tower; yet in a Boston plant employing rough boards set vertically on edge, the boards so swelled and warped that they practically closed the intervening air passages at certain points. This distortion may be noted somewhat in the Colorado Springs tower (Fig. 5).

[3] Conducted by the author and by Messrs. Armstrong and Richardson.

maker, the tower was built by unskilled labor employed about the station, and its total cost, including shell, concrete and brick work, material and labor, was in the neighborhood of $1350, serving a 1000-h.p. engine-driven plant. The shell was designed self-supporting with an independent internal frame work for supporting the weight of the mass. Wooden sheathing could have been used to good advantage, however, and the entire tower constructed by unskilled labor.

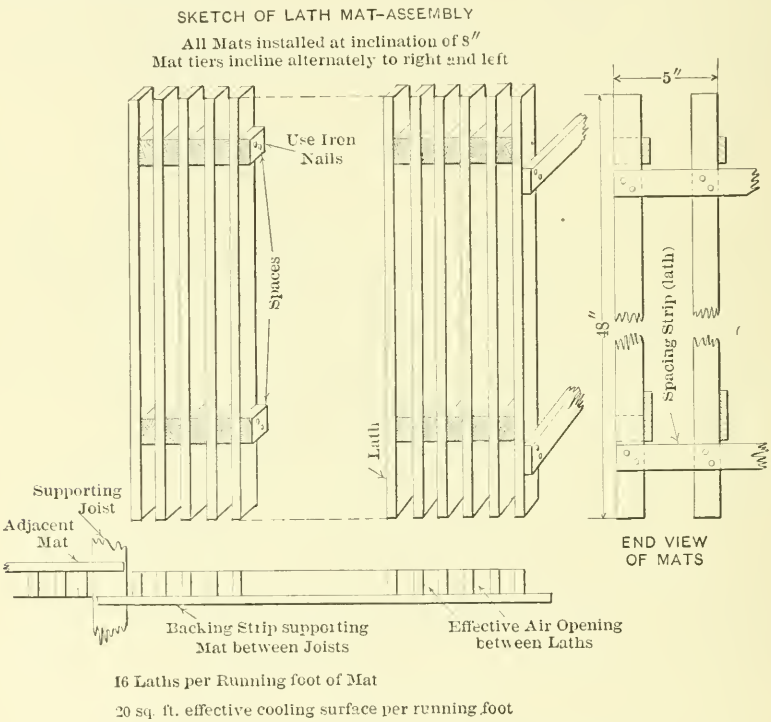

Fig. 10 *a* Details of Sectional Mat Surface

27 The mat surface was constructed of common wood lath, assembled on a form, with iron nails protected from corrosion by being imbedded in the wood. Mat details are shown in Fig. 10 *a*. These lath mats produed a very desirable form of cooling surface. The rough surface kept the descending stream in constant agitation, and there was sufficient slope to prevent free falling water for any great distance, and also to constrain the ascending air to slice upward through the interstices, thereby bringing into use both sides as well

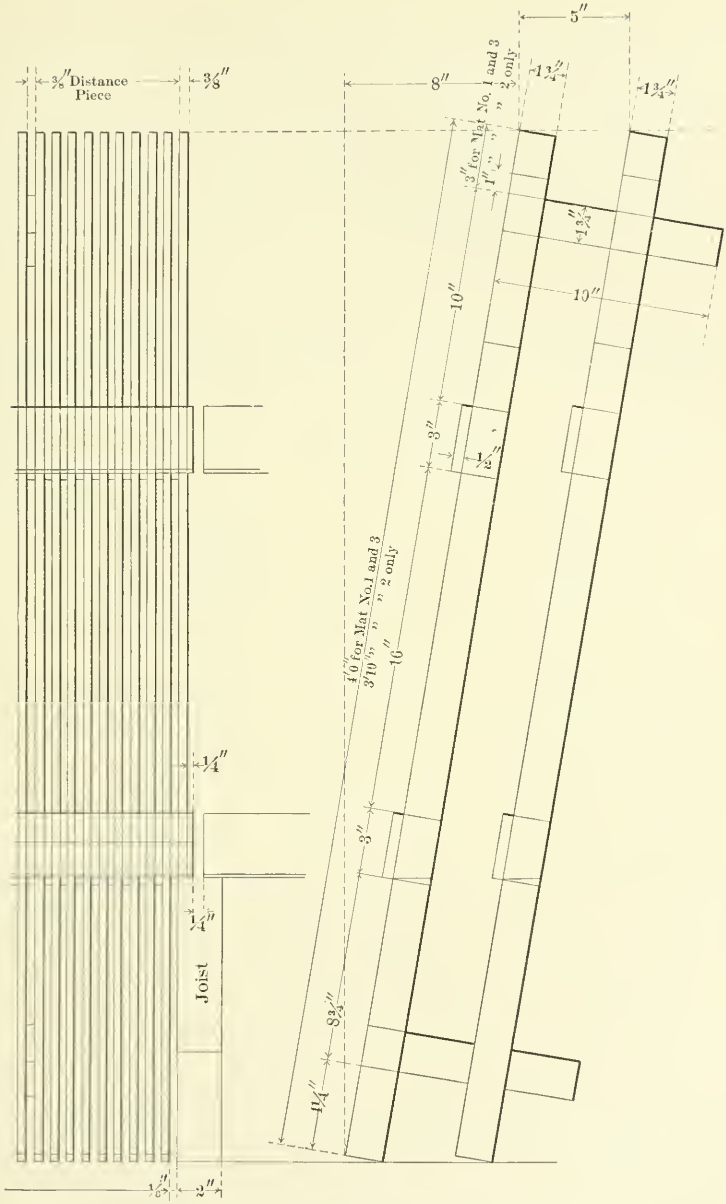

FIG. 10 *b* DETAILS OF SECTIONAL MAT SURFACE

as both edges of the lathe. Thus a cooling surface of approximately 20 sq. ft. per running foot of lath mat was obtained. The various tiers were readily assembled in succession, working from the shell inward until full. Uniform water distribution was effected by means of the pipe-spray system, with laterals spaced like the mats below.

28 Two series of tests[1] were made at Detroit at different times, first, with only the two upper tiers, and finally with all the mats in position. Tables 4 and 5 and Figs. 11 to 13 show the relation between

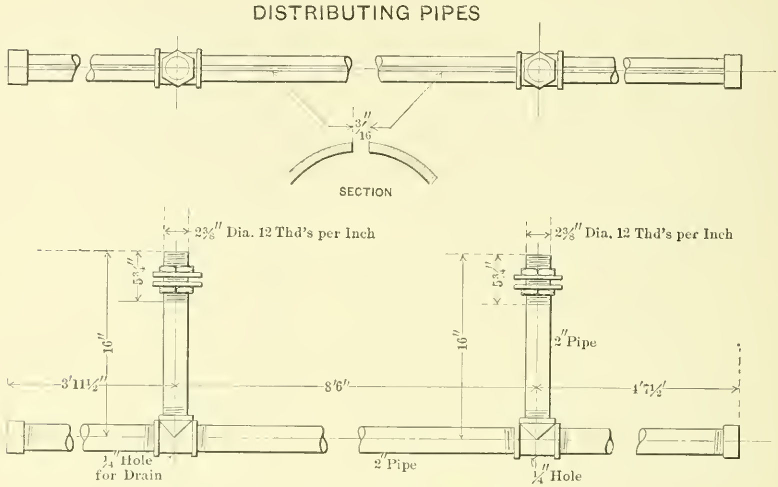

Fig. 10 *c* Details of Distributing Pipes

the various quantities observed. It was very noticeable that the rate of heat dissipation in B.t.u. per sq. ft. per hr. was considerably higher for the uncompleted tower with only about three-fifths of the mats in operation. However, by the addition of the remaining mat surfaces the tower was enabled to work on lower water temperature, and we should therefore expect a lower rate of heat dissipation. This would indicate that the upper tiers of towers were more effective

[1] In this plant the condensing system was not well adapted to economic working. Air and circulating pumps were direct-coupled, making it impossible to control the tower water separately from the condensation. There was considerable air in the system from a long run of exhaust piping; and with no dry-air pumps, a vacuum of 24 in. was normal practice. But the condenser was operated with a temperature differential of 47 deg., so that *with an efficient condenser*, a vacuum of 28 in. might have been obtained with the same tower performance, 16 deg. cooling, 71 deg. cold well.

TABLE 3 COMPARATIVE DATA, DETROIT EDISON TOWERS

TYPE	FORCED DRAFT STATION *A*	NATURAL DRAFT STATION *C*
Rated Engine, i.h.p.	1500	900
Cooling surface, sq. ft.	34,780	24,500
Surface per h.p.	23.2	27.2
Space occupied, cu. ft.	7064	10,850
Space occupied, sq. ft.	175	200
Cost complete	$3900	$1350
Cost per h.p.	$2.60	$1.50
Auxiliaries, e.h.p.	13	..
DIMENSIONS		
Delivery pipe above ground	29 ft. 0 in.	35 ft. 8 in.
Height over all	40 ft. 6 in.	53 ft. 9 in.
Height mat section	17 ft. 0 in.	25 ft. 0 in.
Height stack	12 ft. 6 in.	18 ft. 1 in.
Height outlet	10 ft. 10 in.	9 ft. 0 in.
Diameter tower	14 ft. 10 in.	16 ft. 0 in.
Diameter fan	9 ft. 3 in.	..

TABLE 4 TEST OF NATURAL-DRAFT COOLING TOWER, DETROIT

INCOMPLETE. THREE-FIFTHS SURFACE INSTALLED

TIME	Temperature, Deg. Fahr.					Quantities				
	AIR	HOT WELL*	COLD WELL	WATER COOLING	TOTAL HEAT HEAD†	TOWER WATER LBS. PER HR.	HEAT DISSIPATED B.T.U. LBS. PER HR.	HEAT PER SQ. FT. COOLING SURFACE B.T.U. PER HR.	CIRCULATING WATER PER SQ. FT. LBS. PER HR.	LOAD KW.
1	2	3	4	5	6	7	8	9	10	11
12 noon	34	102	89	13	68	375, 000	4,880,000	332	25	270
1.30	35	106.5	90	16.5	71.5	§ 375,000 / 370,200	6,108,000	415	24.8	315 / 290
2.30	35	106.5	87.5	19	71.5	375,000	7,120,000	484	25	315
3.30	35	113	88.5	24.5	78	375,000	9,000,000	613	25	350
4.30	32.5	100	84	16	67.5	399,000	6,384,000	434	26.6	365
5.00	28.5	103.5	88	15.5	75	445,500	6,900,000	470	29.7	485
6.00	26	125	94	31	99	417,000	12,930,000	880	27.8	655
7.00	24	121	94	27	97	427,000	11,532,000	785	27.4	570
8.00	24	123	94.5	28.5	99	427,000	12,174,000	827	27.4	600

*Assuming a more efficient condenser, say 10 deg. difference, the probable vacuum would be 26 deg. to 27.5 deg. This condenser actually operated at 40 deg. to 50 deg. difference.

†Total heat head = air heating + lost head.

‡Only three-fifths cooling surface installed.

§Difference due to rapid change in load.

TABLE 5 RESULTS OF TEST OF NATURAL-DRAFT TOWER, DETROIT

Complete, Five-Fifths Surface Iestalled

Engines:	Two 400 i.h.p. 300 kw. MacIntosh & Seymour tandem compound engines, overhung generators.			
Condensers:	Worthington surface (admiralty type) 1600-sq. ft. reciprocating wet-air pump and circulating pump.			
Tower:	Wood mat construction, 24,500 sq. ft. evaporating surface, exclusive of shell.			
Test:	March 15 to 16, 1901, 4 p.m. to 4 p.m., 24 hr.			
		A.M.	P.M.	AVERAGE
Weather:	Barometer (abs.), min.	30.22	30.07; 30.14	30.27
	Temperature air, deg.	18.5	25; 30	25
	Relative humidity, per cent	76	82; 58	72
Load:	600 kw. max. to 50 kw. min. Average			244.9 kw.
	Engine Efficiency = 92.5 =875 i.h.p. max. Average			354.8 i.h.p.
Steam:	Weight of condensed steam per hr., lbs			5910.6
	Temperature exhaust steam, deg. Fahr			134.38
	Temperature condensed steam, deg. Fahr			108.78
	Weight of steam per hr., max. load, lbs			13,500
	Vacuum (abs.) 25 to 19, average about			22
	Vacuum corresponding to temperature exhaust steam			25
	Vacuum possible with good condenser (10 deg. difference)			28
Water:	Circulated per hr., lbs			293,536
	Temperature hot well, average, deg. Fahr			87.50
	Temperature cold well, average, deg. Fahr			71.27
	Vaporization loss per hr., lbs			5,970
Results:	Condenser surface per kw., sq. ft			2.66
	Steam per kw. hr., lbs			24.3
	Steam per i.h.p. hr., lbs			16.66
	Circulating water per lb. of steam, lbs			49.6
	Steam per sq. ft. condenser surface per hr., lbs			3.7
	Circulating water per sq. ft. tower surface, lbs			12.0
	Difference in temperature between exhaust steam and discharge, deg. Fahr			47
Cooling:	Max. 20 deg., min. 3 deg–5 deg. Average			16.23
	Heat dissipated per hr, B.t.u			4,769,000
	Heat per sq. ft. tower surface, B.t.u			195
	Heat per sq. ft. per 1000 lb. water, B.t.u			0.665
Evaporation:	Circulating water, per cent			2.03
	Engine steam, per cent			101
Tower:	Surface per kw. (average load 245 kw.), sq. ft			100
	Surface per kw. (max. load 600 kw.), sq. ft			408
	Surface per 1000 lb. steam max. load, sq. ft			1.82
	Surface per 1000 lb. steam average load, sq. ft			4.14
	Surface per 1000 lb. circulating water per deg. max. cooling, sq. ft			5.22

than the lower. The heat dissipation during the tests on the complete tower ranged from 200 B.t.u. to 300 B.t.u. per sq. ft. of surface per hour under normal conditions, and this could undoubtedly have been increased in a carefully constructed tower with suitable condenser apparatus.

29 In general, the tower showed very little difference in efficiency summer and winter, rather against expectations. Apparently the increased evaporation possible in the higher air temperatures of summer offset the greater conduction of heat in the colder air of winter. In very hot weather, a negligible effect from conduction was apparent, from the fact that at certain maximum loads the vacuum fell rapidly, indicating that the capacity of the tower had been reached, due to complete saturation of air, while in cold weather the vacuum would hold up better at the same load. This shows that with air fully saturated and evaporation checked, the dissipation of heat by conduction in hot weather was quite insufficient to give an appreciable margin of overload.

30 This tower was in constant use for a period of about four and a half years, cooling all of the condensing water for the central station. Depreciation was at first thought to be a serious factor, but later, when the tower was finally dismantled, the frame work and mats were found to be in excellent condition. The only parts showing deterioration were the upper sheets of the tower shell lying above the distributor, where corrosion had taken place owing to the alternate wetting and drying of the surface during the last six months of service in 1905 (10-hr. operation). The mats themselves were as sound as when put in. After a few months' service, the mat surface became coated with scale due to the incrustating properties of the water. This scale would accumulate, crack off and fall to the settling basin.

31 Although fairly successful, this experimental design might have been considerably improved. By straddling the supporting joists in the manner shown in detail in Fig. 10 *b*, the various tiers of mats may be brought together into a practically continuous surface from top to bottom, thus entirely preventing the fall of water (Fig. 12). At the bottom, the obstruction to draft may be prevented by employing deflecting troughs under each mat, to convey the water to the center of the tower, as in the Moser tower, Fig. 8 *g*. A better distribution system in the form of horizontal slotted laterals discharging upward and over-flowing directly on to the respective mat sections is shown in Fig. 10 *c*.

32 In any system of stationary jets, it is extremely difficult to

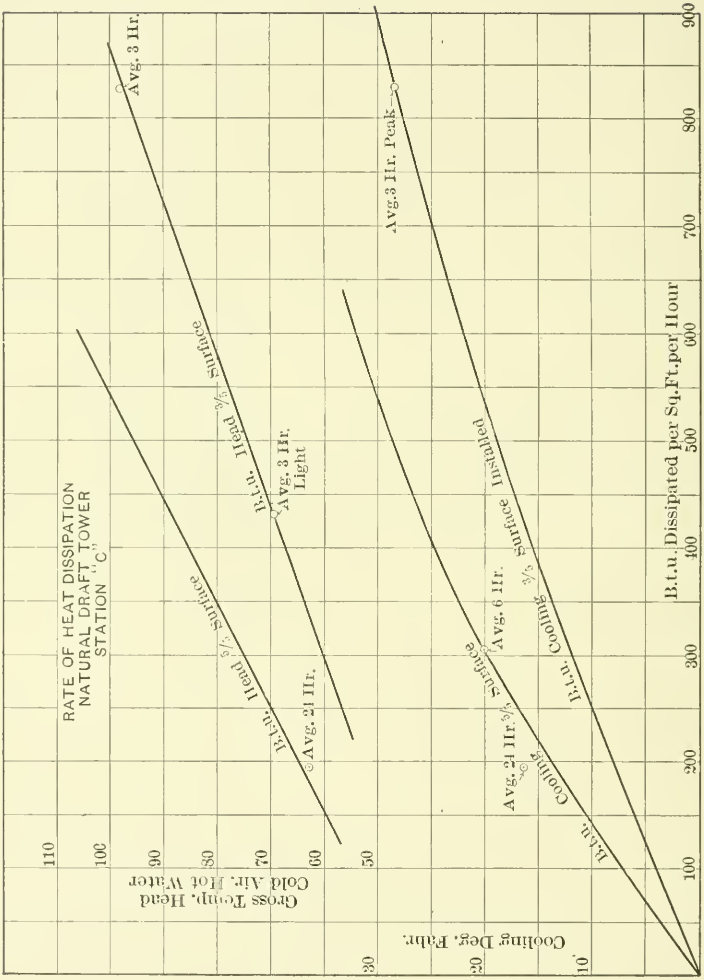

FIG. 11 RATE OF HEAT DISSIPATION OF THE DETROIT TOWER

obtain uniform distribution of water over the entire tower at different rates of flow. With the slotted pipes, it is an easy matter to open or close the slots so as to distribute uniformly, and as they are laid horizontally, this adjustment is permanent. It is also easy to free the laterals from foreign matter, as is not the case with jets. This is because of the ample section of the laterals; whereas any system using a large number of small distributing pipes or apertures involves ultimate trouble from clogging.

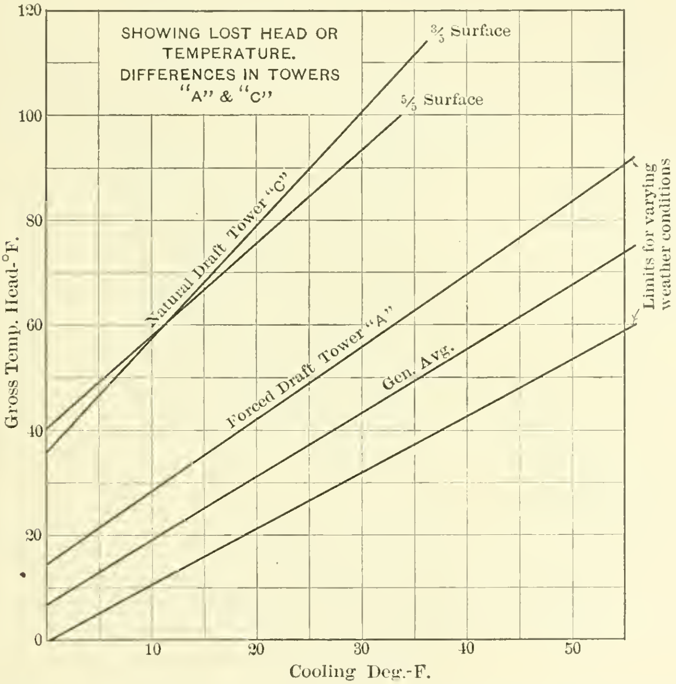

FIG. 12 LOST HEAD OF NATURAL AND FORCED-DRAFT TOWERS

THE EVAPORATIVE COOLER

33 In gas-engine work it is often necessary to economize water to the greatest possible extent. In an Arizona mining plant employing gas engines, where the mine water was so foul and acid as to prohibit entirely its use for cooling jackets, an evaporative cooler was recently constructed of ordinary hot-water radiators arranged in series-parallel, with air forced over the surface by a motor-driven

fan. The well-known counter-current system was employed, and the outfit was fairly efficient, the jacket water being cooled 15 deg. with a power consumption of 5 per cent of the output of the engine.

34 It occurs to the author that by keeping the radiator surface continually wet the effect of evaporation as well as convection might be utilized in cooling. The foul mine water may sometimes be used for this purpose without contaminating the jacket circulation. With an expenditure of $2\frac{3}{4}$ per cent in evaporation, an increase of 24 per cent in cooling would be obtained, assuming the air entering and

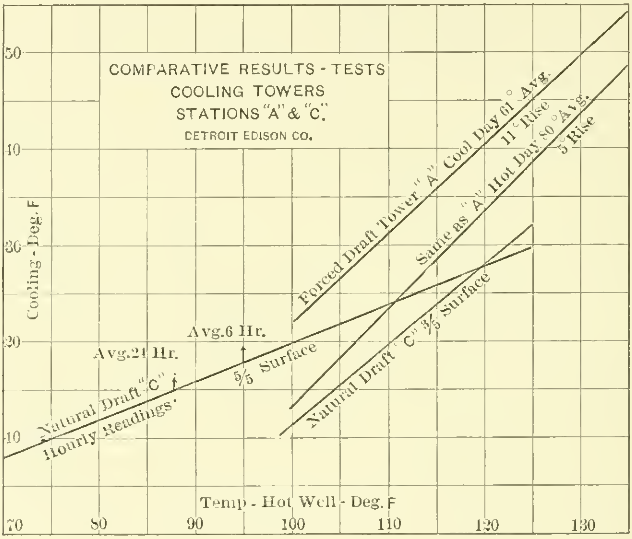

Fig. 13 Comparative Results, Natural and Forced-Draft Towers

leaving to be fully saturated (Fig. 15). This system has been attempted in connection with steam condensers, but apparently without much success. The principle seems entirely logical, but the difficulty of maintaining tight joints with thin-walled tubes of sufficient diameter to permit of the passage of the proper amount of air, would seriously detract from the effectiveness of this apparatus by reason of air leakage. The low vacuum shown during tests of such apparatus largely confirms this supposition. For gas-power plants, however, the type seems admirably suited.

STANDARDS OF DESIGN

35 The cooling tower should be designed with the same flexibility as other good power-plant apparatus, as regards capacity under various conditions of operation; it is subject to the same peak-loads as the prime mover. As a matter of fact, relatively more heat must be

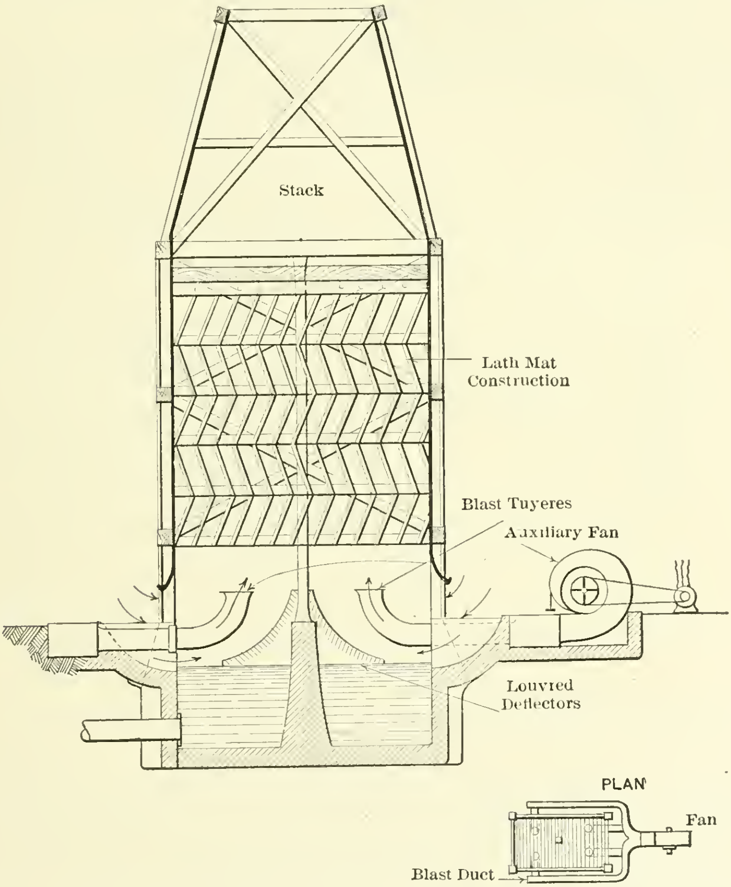

Fig. 14 Proposed Combination Tower With Natural and Auxiliary-Fan Draft

abstracted by the tower during peaks owing to the higher steam consumption of a steam engine per horsepower-hour on overloads. Consider, for example, a normal central station load. The evening peak seldom extends over three hours, and usually the most severe demands

on the generating apparatus occur within a period of one hour. Here, then, a definite overload capacity in the cooling tower is as desirable as in the engine or boiler; and some means should be employed to relieve during these peaks the tower which would have ample capacity to operate unaided during the remainder of the day.

36 Again, consider the comparatively short periods of unfavorable weather in normal climates. Reports[1] from the Butte plant (Table 2) reveal a mean temperature of 41.6 deg. fahr. Yet there were 99 days of the year in which the temperature was above 70 deg.; 50 days above 80, and three days above 90 deg. Fahr. Taking 70

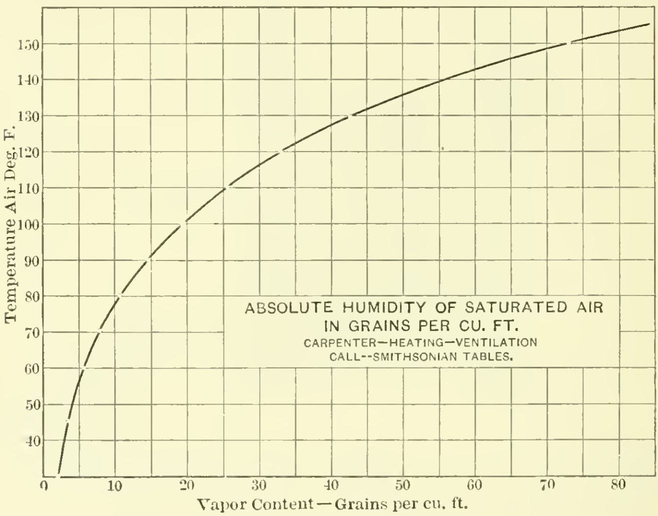

Fig. 15 Vapor-Content in Air at Various Temperatures

deg. as an empirical standard, it is apparent that for two-thirds of the year this temperature would not be exceeded. But careful *hourly* observations at Butte show that a temperature of 70 deg. was exceeded only for 681 hr. throughout the year; i. e., *7.9 per cent of the actual time.*

37 A study of Pittsburg conditions shows similar results (Table 1). Average throughout the year, 52.3 deg. The temperature during June, July and August averaged 10.5 days per month above 85 deg., and the humidity, 15.3 days per month above 80 per cent.

[1] Provided by Mr. Gerry.

Although the actual *hours* of maximum are not available from the Weather Bureau reports, it is safe to say that these unfavorable atmospheric conditions existed not more than one-tenth of the daily period, or 2.5 hr.

TABLE 6 OPERATING DATA, OPEN-SCREEN TOWERS

MT. WHITNEY POWER CO., VISALIA, CAL.

Tower designed for 1500 kw.—2000 kw. at 27-in. vacuum	
Horizontal screen surface, sq. ft.	9550
Circulating water handled, gal. per hr.	1,720,000
Rate of circulation, lb. per sq. ft. per hr.	1500
Dimensions, ft.	30 by 47 by 15 high
10 tiers galvanized iron screens.	5 mesh per in.
Cost of tower including concrete form	$2,000
OBSERVATIONS, OCTOBER 23, 1906	
Maximum load carried, 5.20 p.m., kw.	1130
Temperature atmosphere, deg. Fahr.	55
Depression, wet bulb thermometer, deg.	8.5
Relative humidity, 50 per cent absolute, gr. per cu. ft.	2.35
Temperature incoming hot water, deg. Fahr.	110
Temperature outgoing cold water, deg. Fahr.	100
Cooling, deg. Fahr. (minimum for day)	10
Vacuum carried (ref. 30-in. barometer), in. Hg.	26.6
Difference between temperature steam and condenser discharge	
Possible vacuum (10 deg. difference in condenser)	
Maximum cooling for day (730 kw.), deg. Fahr.	16

Data from Hunt, Mirk & Co., Engineers, San Francisco, Cal.

38 It is apparent from the above that the problem of maximum capacity in cooling towers involves a condition of peak load existing only 5 per cent of the time, and high temperature only 8 per cent of the time. Moreover, these maximum demands will not generally occur at the *same hours* of the day. In the example cited in Par. 11, 5 deg. difference in the condenser, the maximum permissible air temperature would be 81 deg.; the more efficient the condenser, the higher the allowable air temperature. Yet at Butte, the temperature of 85 deg. was exceeded during only 22 days of the year, or 51 hr. This is equivalent to 2.5 hr. during mid-day and less than 0.6 of 1 per cent of the total time.

39 Is it, therefore, good engineering to design a cooling tower installation with a vacuum-producing capacity *large enough for any*

and all emergencies; or, on the other hand, to provide auxiliary means for assisting during these brief periods of maximum demand, while keeping the proportions of the tower within reasonable limits for normal operation? Might not even a considerable impairment of vacuum under the most unfavorable operation be better tolerated than the increased expense of equipment suited to maximum demand?

40 This, of course, applies particularly to natural-draft towers. Flexibility already exists in the forced-draft tower through the speeding of the fans; but even here there are some drawbacks owing to the high velocities already employed for normal working. Any large increase in the velocity of the fan may seriously disturb the uniformity of air distribution over the tower surface and give rise to eddies destructive to efficiency. That this condition exists, is very plainly shown by a survey of the discharge velocity by means of an anemometer. Examination of one defective installation by this method revealed the fact that fully one-third of the area was practically ineffective and that reverse currents actually took place in some parts. The air-distribution problem is exceedingly important, and more so in the forced-draft than in the natural-draft tower, where low velocities favor uniformity.

"BOOSTER" TYPE OF TOWER

41 The natural-draft tower is of itself ill-adapted for operating with a fixed temperature head. It thrives on the weakness of the condensing system. The lower the vacuum, the better the tower works, because of the increase in temperature head. And as this is clearly a problem of chimney design, the only way out of the difficulty is apparently by some method of auxiliary draft. As the specific heat of air is about 0.23, it is evident that an increase of 25 per cent in heat dissipation would require roughly double this increase in quantity of air, in order to maintain the same temperature conditions. This, however, is well within the capacity of a comparatively small fan auxiliary.

42 There are two methods of accomplishing this result:

a By locating in the stack an induced-draft fan which normally remains idle.

b By installing at the base of the tower a forced-draft system so designed as to supplement the natural draft without causing a back-flow.

43 An example of *a* is used in the cooling towers at Gary, West Va. (Fig. 2). Although designed for constant service, the arrangement of the stack fan is precisely as suggested. Whether the Pelton type of motor, direct-connected to the fan, is superior to belt or chain drive from a motor mounted on the outside of the tower, is a question of mechanical convenience: the essential elements are present.

44 The second suggested arrangement is crudely shown in Fig. 14. The auxiliary air is delivered to the tower through four "L"-nozzles supplied from a concrete duct surrounding the base of the tower. With this arrangement, the natural draft under the base of

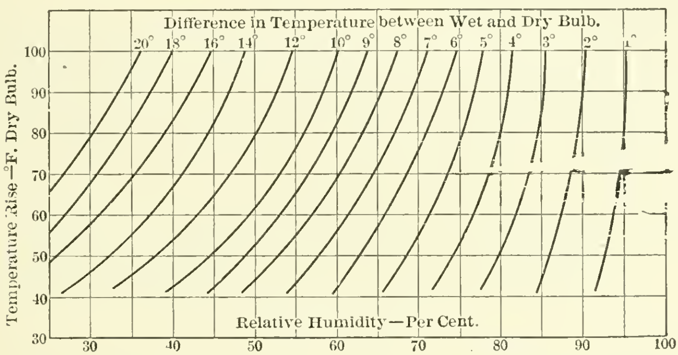

FIG. 16 HUMIDITY CHART FOR WET-BULB THERMOMETER

the tower might tend to be reversed owing to the back-pressure resulting from the blast. It is believed, however, that with a fairly open mat structure such as has been described above, the introduction of four auxiliary blast ducts would serve only to entrain more air and further assist the tower in the absorption of heat.

45 Of the two systems, the former has the advantage of being already put into practice. However, there is to be said in favor of the latter that no working parts, such as fan bearings, belt transmission, etc., are in the current of vapor; and with a tower operated intermittently, corrosion is an important matter, as was proved by the deterioration of the upper-sheets at Detroit. Furthermore this system lends itself more readily to a square or rectangular-shaped tower, which may be desirable in large sizes.

CONCLUSIONS

46 Improved types of cooling towers are in active demand for high-grade power plants both steam and gas, especially for low-pressure turbine installations.

47 Effectiveness of working is largely dependent on efficiency of condenser, i. e., minimum temperature difference between steam and discharge water is desirable to increase the temperature head on the tower.

48 Cooling towers are particularly adaptable to gas power plants. The bulk of the tower is reduced by the high temperature head available with hot jacket water.

49 Elements of most effective design; avoid free falling water; maximum retardation of descent with minimum obstruction of draft; insure uniform distribution of water and air; provide the maximum exposed wetted surface for a given bulk and an interrupted descent of fluid film.

50 In locations of low humidity simple forms of construction usually serve the purpose, except where ground space is valuable.

51 Sectional lath mat type of tower well adapted tonatural draft work. The construction suggested is simple, durable and inexpensive.

52 Normal rate of heat dissipation obtained by lath mat construction, 200 B.t.u. per sq. ft.

53 Auxiliary fan "booster" suggested as the best means of obtaining the desired overload capacity—a combination of natural and forced draft. Overload conditions (high temperature, humidity or load) usually last but a small percentage of the time—1 to 5 per cent. Natural draft suffices for the major portion.

THE PITOT TUBE AS A STEAM METER

By Prof. Geo. F. Gebhardt, Chicago, Ill.

Member of the Society

Steam meters may be conveniently grouped in two general classes, which, for lack of more suitable names, may be designated as *a*, series meters and *b*, shunt meters.

2 The series meter is an integral part of the piping, the entire mass of fluid to be measured passing through the apparatus. The St. John's and Venturi meters are the best known of this class. In the former the *volume* of fluid passing is determined by the rise and fall of a weighted plug valve and in the latter the *velocity* of flow is determined by the well-known principles of the Venturi tube. Both are indicating instruments and show only the rate of flow.

3 In the shunt meter only a portion of the steam to be measured is diverted through the apparatus, the velocity of flow through the shunt being an indication of that in the main pipe. In this class one or more small openings ½ in. or less in diameter suffice for attaching the apparatus to the pipe. One instrument suitably calibrated may answer for any size of pipe. The Pitot tube forms the basic principle of practically all meters of this class.

4 It is the object of this paper to describe a number of applications of the Pitot tube for steam measurements as constructed and tested at the Armour Institute of Technology.

5 The Pitot tube was first used by its inventor, Pitot, in 1837, in the measurement of the flow of water and since then has been successfully used in measuring the flow of many fluids and all true gases. Considerable difficulty has been experienced, however, in its application to vapors condensable under normal conditions of operation; and so far as the writer knows, no commercially successful instrument is on the market.

6 Many of the instruments are interesting laboratory devices and are of considerable value for experimental investigations; but on

account of the great number of variables involved, fall short of being practical commercial instruments. Fig. 1 illustrates the most common and the least accurate application of the Pitot tube for measuring the flow of condensable vapor in a pipe. S is the static nozzle at right angles to, and D the dynamic nozzle facing the current. U is an ordinary manometer partially filled with mercury. When there is no flow the mercury in columns N and W will be on the same level and the upper portions will be filled with condensed vapor. When there is a flow the mercury will be depressed as indicated and the difference in height H of the mercury columns in the two tubes will be

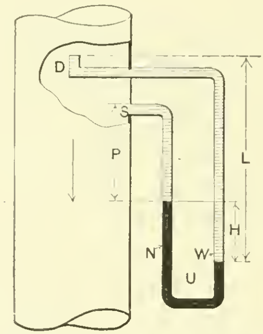

Fig. 1 Pitot Tube with Mercury Manometer

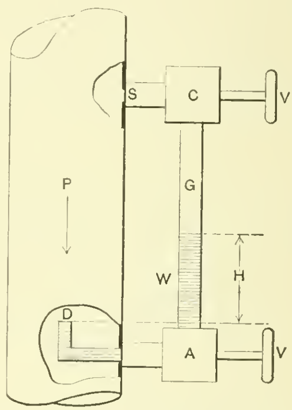

Fig. 2 Simple Gage-Glass Meter with Self-Adjusting Water Column

a measure of the velocity of flow in the main pipe. On account of the great density of mercury and the variation in height of the condensed vapor above the mercury this application of the Pitot tube has very little value scientifically or commercially. For example: With dry steam at 100 lb. gage, a velocity of 8000 ft. per min. would give a depression H of only one in. and an error of 1/100 in. in measuring H would mean an error of 40 ft. per min. in the velocity.

7 In Fig. 2 is shown the original apparatus designed by Prof. R. Burnham of the Experimental Department of Armour Institute of Technology and the writer, in which the water of condensation is used as a self-adjusting column in place of mercury. This embodies the basic principle of many of the meters constructed later.

8 Referring to Fig. 2, A and C are two ordinary water gage cocks

and G an ordinary glass tube. Gage C is connected to the static nozzle S and gage A to the dynamic nozzle of a Pitot tube. The height of water H is directly proportional to the velocity of steam flowing through pipe P and automatically adjusts itself to the variations in velocity; thus, for decreasing velocities the water in glass G discharges itself through tube D until the water column H balances the velocity pressure in pipe P, and for increasing velocities condensation from the upper part of the instrument accumulates and the water column H rises until a balance is effected for the higher velocity.

9 The velocity of flow is determined by the well known equation:

$$V = c\sqrt{2gH} \tag{1}$$

in which

V = maximum velocity of flow, ft. per sec. Dynamic nozzle D is inserted in middle of pipe where the velocity is a maximum.

c = coefficient determined by experiment.

g = acceleration of gravity = 32.2.

H = height of a column of steam equal in weight to water column H.

Equation (1) may be expressed:

$$V_1 = 139\,c\sqrt{h\frac{d_w}{d_s}} \tag{2}$$

in which

V_1 = maximum velocity, ft. per min.

d_w = weight of 1 cu. ft. of water in gage glass G.

d_s = weight of 1 cu. ft. of the steam or mixture in pipe P.

h = height of column H in inches.

The weight of steam flowing per hour may be determined by substituting the proper quantities in equation (2), thus:

$$W = 58\,acr\sqrt{h\,d_s d_w} \tag{3}$$

in which

W = weight of steam flowing, lb. per hr.

a = area of the pipe, sq. in.; other notations as in (2).

r = ratio of the mean velocity to the maximum.

10 Equations (2) and (3) are general and are applicable to any size pipe and any pressure and quality of steam. For a given size of pipe, say 3 in. (extra heavy), and a given pressure of steam, say 70 lb. gage, equations (2) and (3) assume the following simple forms:

$$V = 2435\,cr\sqrt{h} \tag{4}$$

$$W_s = 1292\,cr\sqrt{h} \tag{5}$$

11 Tests with pipes 1 to 6 in. in diameter gave r a value of 0.79 to 0.84. For a 3 in. extra heavy pipe this value was 0.82 and remained practically constant for all velocities and pressures (atmospheric to 100 lb. gage.) Substitute this value of r in (4) and (5),

$$v = 1996\ c_1 \sqrt{h} \tag{6}$$

$$w = 1060\ c_1 \sqrt{h} \tag{7}$$

in which

v = actual mean velocity, ft. per min.
w = actual weight of steam flowing, lb. per hr.
c_1 = a coefficient determined by experiment.

Coefficient c_1 varied from 0.8 to 1.2 for the simple instrument in Fig. 1.

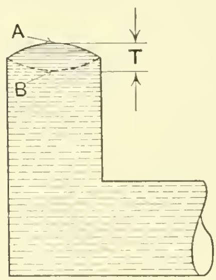

Fig. 3 Influence of Surface Tension on Height of Water in Dynamic Nozzle

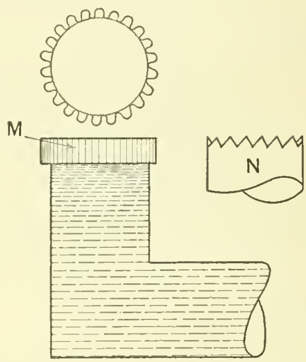

Fig. 4 Dynamic Nozzle with Arrangement for Maintaining a Constant Level of Overflow

12 Variation in the value of c_1 was found to be due to

a Fluctuation in height T (Fig. 3), at the end of the dynamic tube due to surface tension. With a plain tube this variation amounted to as much as 0.25 in.
b Variation in density of water column.
c Capillarity in gage glass G.
d Aspiration in static tube at high velocities.

13 (*a*) A number of devices were constructed for eliminating the variation in height of T in the dynamic nozzle but all proved inefficient, except that shown in Fig. 4. By serrating the tube as indicated in N, Fig. 4, and surrounding it with a corrugated ferrule M, thereby forming a series of capillary tubes, the variation was practically eliminated, amounting to but 0.02 in.

14 (*b*) The variation in density of the water column is an inherent defect of this type of meter and cannot be remedied in this simple form of apparatus. The experiments gave a range in temperature

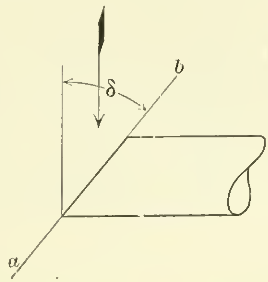

Fig. 5 Static Nozzle Corrected for Aspiration

of 150 to 300 deg. fahr. resulting in a maximum possible error of 6 per cent. For high velocities the fluctuation in temperature is negligible but for low velocities the range may be considerable.

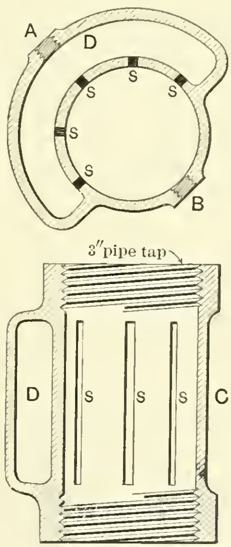

Fig. 6 Device for Determining Aspiration Effect

15 (*c*) Capillarity in the gage glass increases as the diameter of the glass decreases and may be considerable in tubes of small bore. With a $\frac{3}{4}$ in. tube it amounts to 0.05 in., hence its influence is negligible for high velocities.

16 (*d*) Aspiration in the static tube is appreciable only with velocities above 6000 ft. per min. It may be entirely eliminated by beveling the tube as indicated in Fig. 5. In this device the dynamic and aspiration effects neutralize each other and only the true pressure is recorded. The aspiration effect was determined by means of the apparatus illustrated in Fig. 6. It consists of a special fitting containing a chamber in communication with the main pipe, but so constructed that the velocity of flow in the chamber is practically eliminated. The difference in pressure between the two openings *A* and *B* is due to aspiration. Further experiments are necessary to show whether any fixed angle is applicable to all velocities.

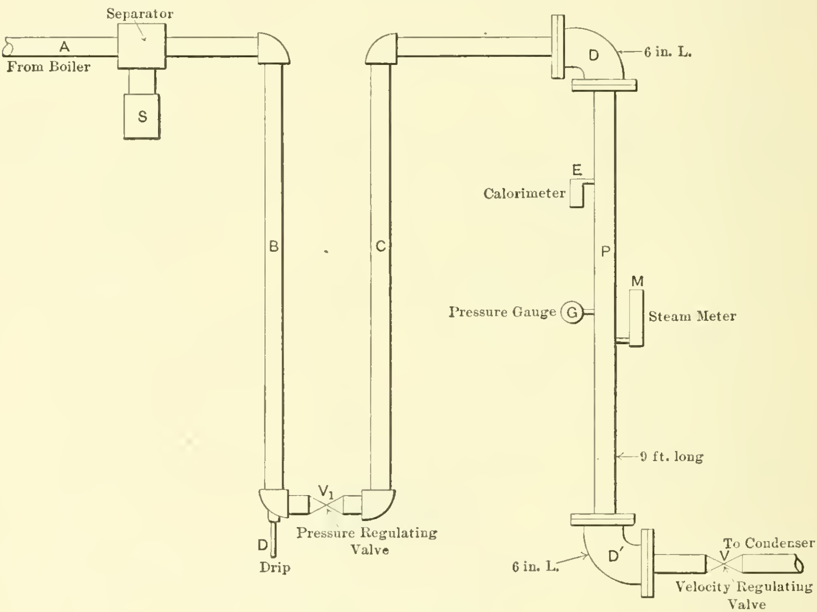

FIG. 7 DIAGRAMMATIC ARRANGEMENT OF PIPING FOR TESTING STEAM METERS

17 A simple construction, as illustrated in Fig. 2, with $\frac{1}{2}$ in. pipe connections and $\frac{3}{4}$ in. gage glass, fitted with dynamic tube, as illustrated in Fig. 4, and static tube as in Fig. 5, is an accurate means of indicating the true velocity of flow and the actual weight of water discharged for all velocities above that corresponding to $1\frac{1}{2}$ in. of water. For lower velocities any error in reading is so large in proportion to the entire head as to make considerable difference in results. The scale may be graduated to read velocities in feet per minute and the water rate in pounds per hour.

TABLE 1 TEST OF SIMPLE GAGE GLASS METER

STEAM PRESSURE 70-LB. GAGE. STEAM DRY. 3-IN. EXTRA HEAVY PIPE.

h	Velocities Feet per Minute			Weights Pounds per Hour			
	Actual Mean	Maximum by Meter	Ratio	Actual	Meter	Difference	Error
$2\frac{1}{8}$	2860	3528	1.23	1516	1545	29	1.88
$3\frac{3}{4}$	3890	4685	1.20	2062	2052	10	0.48
$5\frac{1}{8}$	4530	5480	1.21	2400	2400	0	0.00
$7\frac{3}{8}$	5360	6570	1.22	2852	2878	26	0.91
$9\frac{3}{8}$	6170	7405	1.20	3270	3240	30	0.92
		Average	1.21				

Mean Radius 0.82. Coefficient of Meter = 0.82 × 1.21 = 0.992 or practically unity.
Equation for meter: $V = 1996\ h$, and $W = 1060\ h$.

18 The results of a few tests of this simple device are given in Table 1, and the arrangements of piping for conducting the tests is shown diagrammatically in Fig. 7. The results are also plotted in Fig. 8. The curves give the weights as calculated from equation (7) and the small circles the weights as determined from the condensed steam. It will be noted that coefficient c_1 is unity and no calibra-

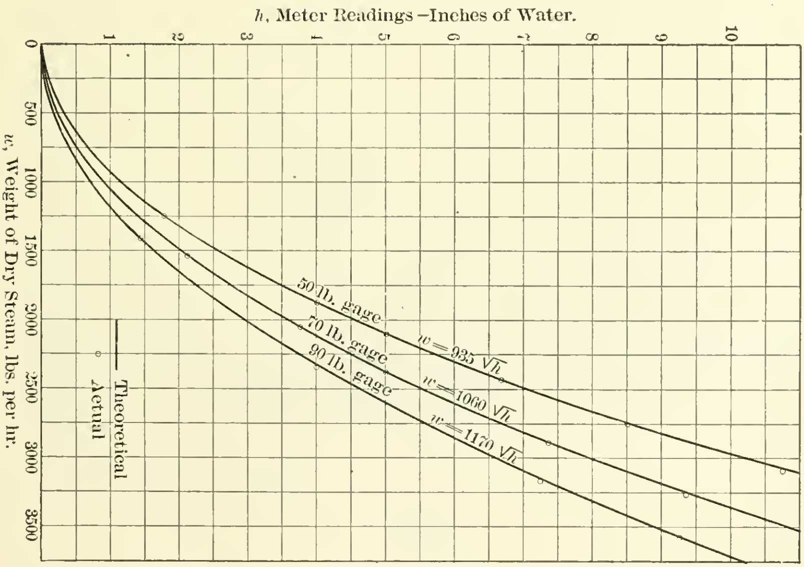

FIG. 8 TEST OF SIMPLE GAGE-GLASS METER, 3-IN. EXTRA HEAVY PIPE

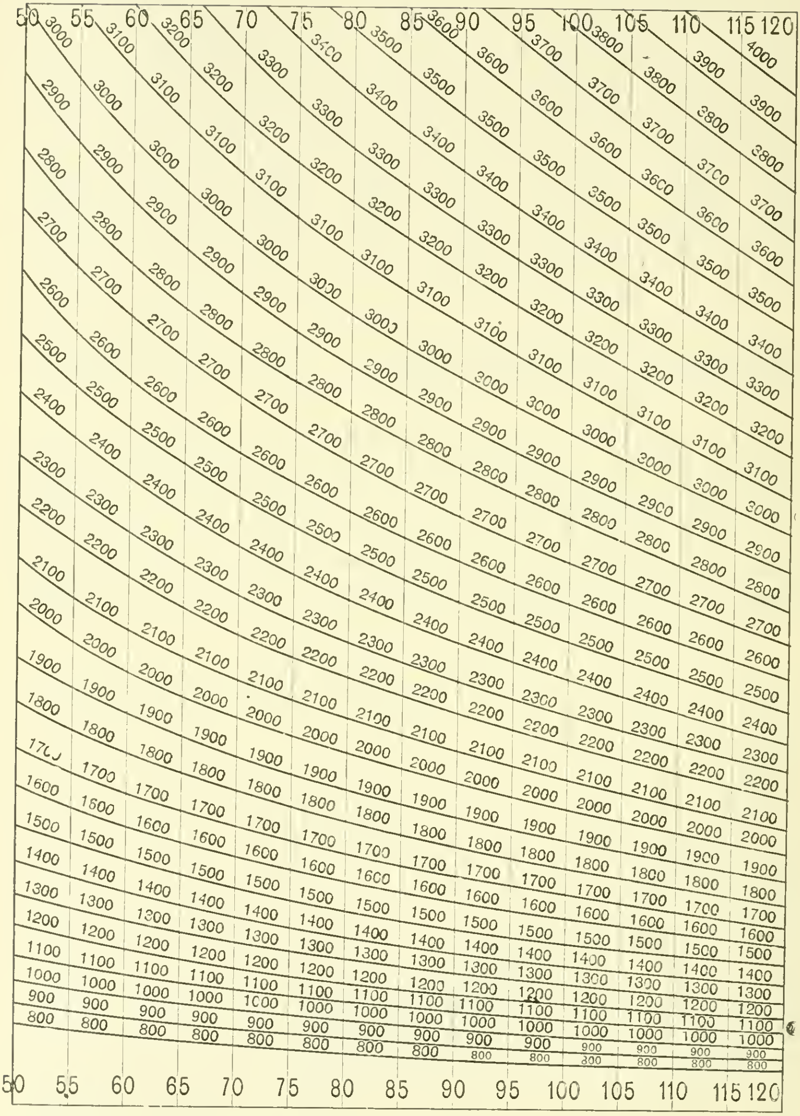

Fig. 9 Type of Chart Giving Wide Pressure Range for Given Size of Pipe

tion is necessary. Tests on 1-in., 2-in., 3-in., and 4-in. standard pipe gave a coefficient of practically unity. The tests tend to show that for a given size of pipe and a constant pressure and quality of steam

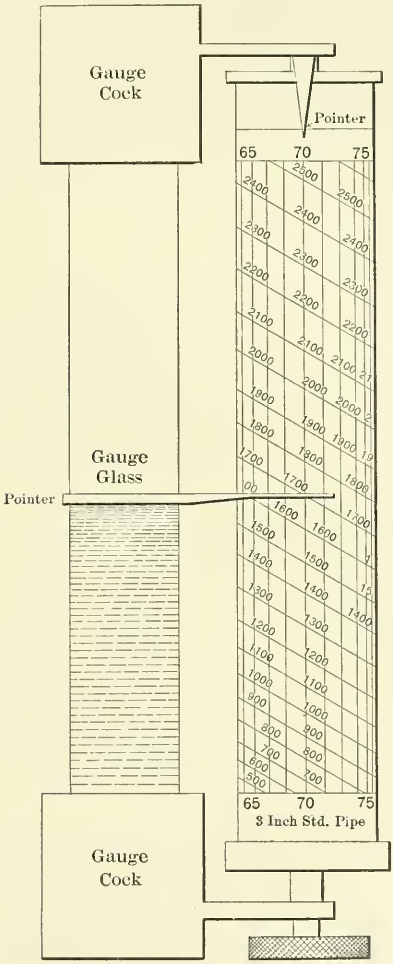

Fig. 10 Method of Mounting Chart

the actual mean velocity and weight of water may be accurately determined by equations:

$$v = 139 \sqrt{h \frac{d_w}{d_s}} \tag{8}$$

$$w = 58a \sqrt{h d_w d_s} \tag{9}$$

This is strictly true for continuous flow only. Interrupted flow, as in connection with reciprocating engines, creates a fluctuating water column and it is difficult to obtain the mean readings. For engines making over 100 strokes per minute the height of water is practically constant but for lower speeds the fluctuation increases with the decrease in speed. By suitably throttling the lower valve *V*, water column *H* may be made to assume a fairly approximate mean value for speeds as low as 20 strokes per minute in engines taking steam full stroke.

19 The limitations of the simple gage glass meter for commercial purposes are:

a It is purely an indicating device and readings must be taken frequently to obtain average results.

b A scale graduated for a given set of conditions is accurate only for these conditions, the degree of accuracy varying with the fluctuation in steam pressure, change in quality of the steam and variations in temperature of the water column. A convenient form of chart for a given size of pipe and for a wide pressure range is illustrated in Fig. 9. The chart is wrapped around the drum, as in Fig. 10, and set to correspond to the given pressure. The height of the water column transferred to the chart by a suitable pointer gives at once the weight of steam flowing.

c Rapid increase in flow may cause the water in gage glass *G* to be blown out requiring several minutes for sufficient condensation to collect and balance the velocity head.

d Inaccuracy for velocities below that corresponding to a $1\frac{1}{2}$ in. water column, or roughly, 2000 ft. per min. for pressures over 70 lb. gage.

e Cannot be used for measuring the flow of highly superheated steam except for practically constant flow and constant degree of superheat. With highly superheated steam a condensation chamber must be fitted to upper gage cock *C*, Fig. 2.

20 Fig. 11 shows a modification of the simple gage glass meter with simple pipe connection, which requires the pipe line to be tapped in only one place. It may be set at any angle with the horizontal, thereby increasing the sensitiveness of the readings.

21 Fig. 12 shows an application of the gage glass meter in which many of the defects of the simple gage glass device are eliminated.

The error due to the variation in water level at the end of the dynamic nozzle is entirely eliminated by making the tube a "dry" tube; i. e., water of condensation is not returned through the dynamic nozzle. The temperature of the water in the gage glass is practically constant, all condensation from the static end being discharged through drain F to the chamber below, and all water carried over by the dynamic end being discharged into pipe P directly to overflow G. The area and volume of chamber M is so large compared with that of glass W that sudden variations in flow do not materially affect the level of

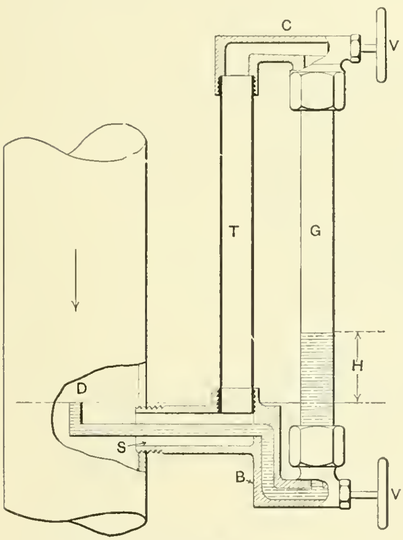

Fig. 11 Gage-Glass Meter with Single Pipe Connection

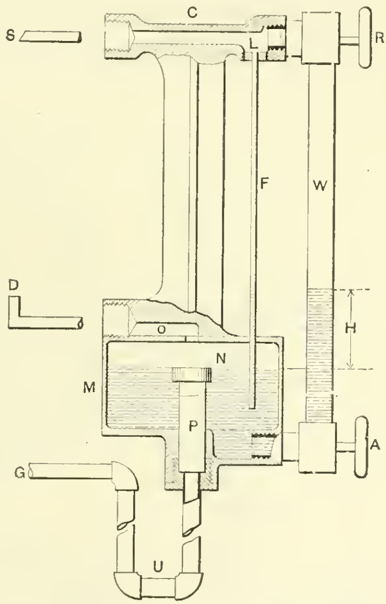

Fig. 12 Gage-Glass Meter with Dry Dynamic Tube

water in M and cannot blow the water out of glass W. The only defect in the instrument is the error due to capillarity in glass G, which, as stated before, amounts to but 0.05 in. for a $\frac{3}{4}$ in. tube.

22 The operation is as follows: Velocity pressure is transmitted through tube D and opening O, into the body of chamber M. This pressure acting on the surface of the condensation in the chamber forces water into glass W until a balance is effected. Condensation is discharged continuously through pipe P and water seal U of the main pipe. Tests of this meter gave practically theoretical results

for all velocities ranging from the equivalent of a $\frac{1}{2}$-in. water column to 10-in.

23 Fig. 13 shows an application of the self-adjusting water column for very low velocities, 2000 ft. per min. and under. Glass ball B rises and falls with the water column, transmitting its motion through levers L and N, gear sector G and pinion P, to permanent magnet, M. The latter transmits its motion to magnet M' outside the casing. Pointer C is fastened to magnet M'. Thus any motion of ball B is multiplied by pointer C and indicated on dial K. Magnets M and

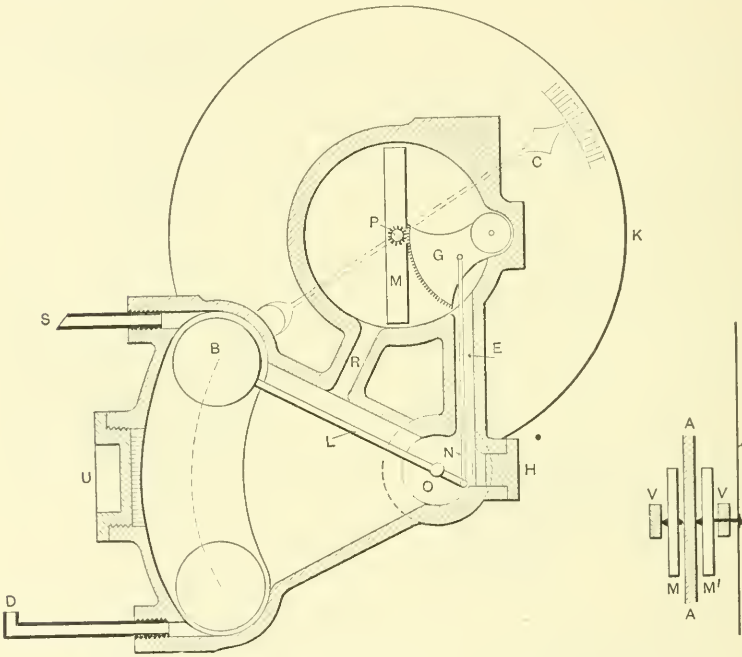

Fig. 13 Meter with Self-Adjusting Water Column for Low Velocities

M' are independently mounted on pivot bearings, M within the casing and subjected to steam temperature, the other outside the casing. Motion of M is transmitted magnetically to M' through the casing, thus doing away with stuffing boxes. The relative positions of magnets and casing are illustrated in the lower corner of Fig. 13. On account of the angularity of the connecting links and the frictional resistances, small as they are, the dial graduations cannot be conveniently calculated but must be calibrated by experiment.

24 This instrument is very sensitive, indicating velocity changes of 20 ft. per min. When connected directly to the pipe it is subject to all of the errors of the simple gage glass meter and is altogether too sensitive for accuracy. When connected, however, to the chamber illustrated in Fig. 12 taking the place of the gage glass, velocity changes as low as 20 ft. per min. have been accurately determined.

25 Only a few experiments have been made with this device and further tests are necessary before definite statements can be made relative to its reliability.

26 All of the devices described above are simple indicating mechanisms, and with the exception of the one illustrated in Fig. 13, cannot conveniently be made autographic.

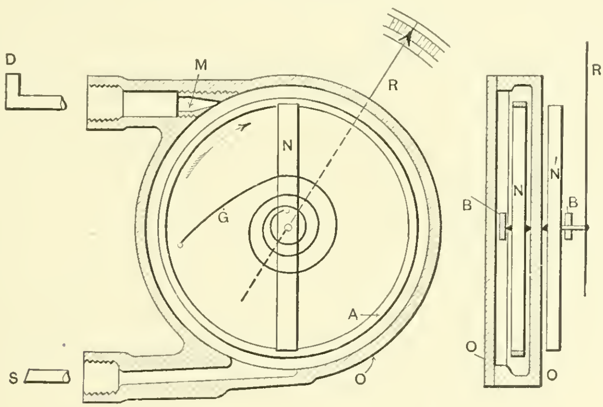

Fig. 14 Indicating Impulse Meter

27 For commercial purposes a steam meter should be autographic, or better still, integrating. The ideal meter is one which shows at a glance the weight of steam flowing for any given period of time and which may be read as one does a watt-hour meter.

28 Fig. 14 shows an application of the Pitot tube for indicating, autographically, the weight of steam discharged and differing basically from those just described. A permanent magnet N forms the spoke of a small aluminum wheel A. Rotation of wheel A is resisted by spiral spring G. D and S are dynamic and static nozzles, respectively, of a Pitot tube. The velocity head discharges a small jet of steam through nozzle M and exerts a force on the periphery of wheel A, tending to rotate it about its axis. The angular rotation increases with the velocity. The motion of wheel A is imparted through the

medium of magnets N and N' to pointer R. By means of a suitable clock-work the angular movement of wheel A may be autographically transferred to a chart giving a continuous record of the weight of steam flowing.

29 By permitting the wheel to rotate and by connecting magnet N' to a series of rotary dials an integrating or total output mechanism is readily effected.

30 Experiments are now being conducted with the autographic and integrating devices just described, but sufficient data are not yet available as to their respective merits.

COMMENT ON CURRENT BOOKS

CONCRETE, PLAIN AND REINFORCED. By Frederick W. Taylor and Sanford E. Thompson. *John Wiley & Sons, New York.* Second Edition. 1909. Cloth, 6 by 9; xi + 807 p.; 249 illustrations. Price $5.

This second edition of the book brings the treatment of the subject up to date, more than 200 pages of text and tables having been added. The new chapter one outlines the essentials of concrete construction and the errors frequently made, with references to pages in which more detailed information is given. The specifications for cement and concrete in chapter iii, and chapter ix by W. B. Fuller on proportioning, have been revised. Chapters xiv and xv on mixing and depositing have been enlarged, giving more recent tests on the strength and permeability of concrete. Chapter xxi on reinforced concrete design has been increased from 51 to 131 pages. Tables and diagrams for use in designing cover twenty pages, and a complete example of floor design gives the mathematical computations in detail. Prof. F. P. McKibben has written the chapter on arches, discussing the design of the arch by the elastic theory, a complete example being given with all the steps in the calculations. Chapter xxix is a brief history of the development of cement manufacture, with an outline of modern processes. The list of references to concrete literature in chapter xxxi has been increased over 50 per cent. In order to simplify the formula used, the demonstrations have been placed as far as possible in footnotes and appendices.

Contents by chapter headings: Essential Elements in Concrete Construction; Concrete Data; Elementary Outline of the Process of Concreting; Specifications; The Choice of Cement; Classifications of Cement; Chemistry of Hydraulic Cements, by Spencer B. Newberry; Standard Cement Tests; Speecial Tests of Cement and Mortar; Strength and Composition of Cement Mortars; Voids and other Characteristics of Concrete Aggregates; Proportioning Concrete, by William B. Fuller; Tables of Quantities of Materials for Concrete and Mortar; Preparations of Materials for Concrete; Mixing Concrete; Depositing Concrete; Effect of Sea Water upon Concrete and Mortar by R. Feret; Laying Concrete and Mortar in Freezing Weather; Fire and Rust Protection; Water Tightness; Strength of Plain Concrete; Reinforced Concrete Design; Arches by Frank P. McKibben; Sidewalks, Basement Floors and Pavements; Concrete Building Construction; Foundations and Piers; Dams and Retaining Walls; Conduits and Tunnels; Reservoirs and Tanks; Cement Manufacture; Miscellaneous Structures; References to Concrete Literature; Appendices.

CONCRETE. By John C. Trautwine, Jr., and John C. Trautwine, 3d. *John Wiley & Sons, New York.* 1909. Cloth, 5 by 7; ix + 190 p. Price $2.

The book is essentially the section on concrete in the latest edition of the authors' Pocket-Book, with the addition of chapters on strength of materials, mortar and sand—also from the pocket-book. Besides dealing very fully with

the characteristics of cement and concrete, the book gives valuable and extensive data regarding the practice of the art,—a feature mentioned in the review of the Pocket-Book below.

Contents by chapter headings: Strength of Materials; Cement Mortar; Aggregates; Reinforced Concrete; Experiment and Practice; Digest of Specifications; Cost.

Civil Engineer's Pocket-Book. Revised by John C. Trautwine, Jr., and John C. Trautwine, 3d. *John Wiley & Sons, New York.* 1909. Nineteenth Edition. Leather, pocket size; xxxii + 1257 p. Price $5.

One of the prominent features of the latest edition of this well-known book is the section on cement and concrete, increased from 17 pages in the 1902 edition to 126 pages in the present one. The section has its own index for ready reference to the "Selected Results of Experiment and Practice;" these data, with the "Digest of Specifications" for general concrete work, make the book an extremely valuable source of information. Revisions of the pages on strength of materials; columns; specifications for steel rails, rail joints, iron and steel; logarithmic trigonometric functions; hydraulics; price list; business directory; and bibliography, have helped to add 300 new pages to the book.

Digest of Data Collected Before the Year 1908 Relating to the Sanitary Condition of New York Harbor. *Martin B. Brown Press, New York.* 1909.

The Metropolitan Sewerage Commission of New York, of which H. deB. Parsons, Mem.Am.Soc.M.E., is a member, has prepared and issued this report for the purpose of making public a digest of the analytical data available up to 1908 relating to the sanitary condition of the waters of New York harbor. The investigations here included contribute materially to an understanding of the conditions which follow the discharge of sewage into harbor waters, but are not presented as a basis for conclusions, further examinations of the water of New York harbor and the procurement of additional data being now in progress.

Betterment Briefs. A Collection of Published Papers on Organized Industrial Efficiency. By H. W. Jacobs. *John Wiley & Sons, New York, 1909.* Cloth, 6 by 9; 240 pages; 136 illustrations. Price $3.50.

This book, as its sub-title indicates, is a collection of papers by the author on the "movement for the betterment of American railroading." The subjects treated are varied, covering the field from shop methods to welfare work for the employees. Though the author writes from the viewpoint of the railroad shop, much that he says may be applied to other fields of industrial activity. The book with its numerous illustrations should make interesting reading; the only criticism that may be made is of the reddish brown tint of the ink used for the text.

Contents by chapter headings: Commercial Tool Methods in Railroad Shops; Improved Devices for Railroad Shops; High-Speed Steel in Railroad Shops; Practical Advice to College Men; Organization and Efficiency in the Railway Machine Shop; The Relation Between the Mechanical and Store Departments; Shop Efficiency; The Square Deal to the Railway Employee.

ROBERT FULTON AND THE CLERMONT. By Alice Crary Sutcliffe. *The Century Co., New York*, 1909. Cloth, 5 by 7½, xv + 367 pages; illustrated. Price $1.20.

The author, Fulton's great-granddaughter, has given an interesting account of Fulton's early life, his work in steamboat navigation leading up to the building of the Clermont, with some description of his work on canals, torpedoes, and submarines. Doubtless this was the author's intention, rather than to reply to the charges that Fulton was a plagiarist and incapable himself of developing the steamboat without the aid of earlier or contemporary investigators. Though the reader may obtain the impression that Fulton would never have built the Clermont without the backing of Livingston, yet in all his work he showed such an indefatigable spirit that it may be assumed that he would have gone far toward attaining his end by some other means. Of the whole matter it may be said that Fulton should not be celebrated for accomplishing a great engineering feat, but rather for making, by whatever means, the first successful commercial application of steam power to navigation. The author has evidently spent much time and care on the book, and many interesting letters and drawings are reproduced.

Contents by chapter headings: Early Life; Robert Fulton in France; The Trial Boat on the Seine; The Clermont; Appendix.

BIBLIOGRAPHY OF THE COTTON MANUFACTURE. By C. J. H. Woodbury, A.M. Sc.D. *Published by the author at Boston, Mass.* 1909. Cloth 7 by 10 213 p. Price $2.

The author's work as secretary of the National Association of Cotton Manufacturers has given him a valuable viewpoint from which to select the important literature of the art. Information has been drawn not only from the manufacturers, but from leading libraries on both sides of the Atlantic, making the list very complete as to works in English, French and German. This work is of value to investigators in the subjects of cotton manufacture, the finishing of goods, or the engineering and mechanical problems pertaining to the matter. It also affords a means of directing examinations into the agricultural, commercial and historical questions relating to cotton. Apart from the cotton manufacture in a technical sense, there are a large number of references to its history and economics bearing upon sociological problems involved in the relations of labor and capital.

Contents: Cotton manufacture; Finishing; Engineering and Machinery; History and Economics; Cotton; Journals.

ALUMINUM HANDBOOK. *Published by The Aluminum Company of America, Pittsburg, Pa.* Size 4½ by 7; 154 p.; illustrated.

Much interesting and valuable information regarding aluminum will be found in this book, which is made up of five pamphlets dealing with the properties of the metal, and its various products. It is attractively bound in leather, with a thumb-index, supplemented by a table of contents for each section. The typographical work is excellent and the illustrations are of a high order.

Contents: Properties of Aluminum; Alloys of Aluminum; Methods of Working Aluminum; Fabricated Aluminum; Useful Tables.

ACCESSIONS TO THE LIBRARY

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Lavorazione e Tempera Degli Acciai. By A. Massenz. *Milano, U. Hoepli, 1909.*

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Testing Asphalt. By Harry Tipper.

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EXCHANGES

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Gift of Appalachian Engineering Association

Hydraulic Power Possiblities of the South. By L. S. Randolph. *Morgantown, 1909.*

Lead and Zinc Ores of South-Western Virginia. By M. M. Caldwell. *Morgantown, 1909.*

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Organization and Engineering Difficulties of the Virginian Railway. By W. N. Page. *Morgantown. 1909.*

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United Engineering Society

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TRADE CATALOGUES

Aluminum Company of America, *Pittsburg, Pa.* Five pamphlets.

Armstrong Cork Co., *Pittsburg, Pa.* Nonpareil Corkboard Insulation. 1909.

H. W. Caldwell & Sons Co., *Chicago, Ill.* Catalogue No. 34; elevating, conveying, and power transmitting machinery. 847 pp.

De La Vergne Machine Co., *New York City.* Oil engines, horizontal, four-cycle, and vertical two-cycle types. 84 pp.

General Electric Co., *Schenectady, N. Y.* Bulletin No. 4691. Small polyphase motors, 6 pp.; No. 4694. Portable sub-stations for electric railways, 8 pp.; No. 4695. G-1 type K enclosed arc lamps, 16 pp.; No. 4698. Luminous arc headlights, 6 pp.; No. 4699. Motor-driven air compressors, geared type, 6 pp.; No. 4700. Switchboard instruments, type R-2, 5 pp.; No. 4701. Emergency straight air brake system, 10 pp.; No. 4704. G. E.-219 railway motor, 15 pp. Price list No. 5210, 8 pp. Folder on contents of November G. E. Review, 3 pp.

Glidden Varnish Co., *Cleveland, O.* Protection of iron and steel against corrosion by acid, and graphite acid-proof coating. 8 pp. Advanced finishes for modern building construction. 8 pp.

Golden-Anderson Valve Specialty Co., *Pittsburg, Pa.* Catalogue No. 12. Valves, steam and water specialties. 68 pp.

Langdon-Davies Motor Co., Ltd., *London.* Size and types of motors, also useful tables. 8 pp.

Sandusky Foundry & Machine Co., *Sandusky, O.* Paper made by "Millspaugh" suction roll process. 20 pp.

Underfeed Stoker Co. of America. *Chicago, Ill.* Publicity magazine, October 1909. 15 pp.

United Electric Light & Power Co., *New York City.* Light, September 1909. 12 pp.

L. J. Wing Manufacturing Co., *New York City.* Bulletin No. 6. "Typhoon" turbine blower for mechanical draft. 15 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society, and these are on file, with the names of other good men not members of the Society who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

080 Experienced draftsman in general rolling-mill work, especially new construction, at a large steel plant in the middle West. State experience and salary expected.

081 Position competent designer of mathematical and optical instruments at Frankford Arsenal, Philadelphia, Pa. Address the Commanding Officer, giving full particulars as to training and experience.

082 Wanted—A thoroughly practical and energetic mechanic to take position as rate fixer on premium work in machine shop building a line of air compressors. Applicant must have had broad experience in practical shop work.

083 Assistant professorship, in charge of design courses in engines, steam turbines, locomotives or gas engines, with assured advancement to full professorship in few years, for the right man. Institution desirous of having its men do outside work. Want a man of ability and experience. Position would pay initially from $1800 to $2000. Location, New York state.

084 Thouroughly competent young man to take a position as assistant engineer, particularly in connection with automobile work. Would like to get in touch with a man who has had shop experience, particularly in connection with heat treatments of steels and other metals.

MEN AVAILABLE

321 Superintendent and manager desires change for larger opportunity. High grade organizer and executive. Specialized on equipment, production, and costs.

322 General manager or assistant, graduate M.E., at present holding similar position, would like to make change; ten years practical experience; good executive ability, best of references.

323 Technical graduate desires position as assistant to superintendent, testing engineer, or similar position; age thirty-three; has employed and had charge of men.

324 Junior, experienced in power-plant design and installation; manufacturing of condensers, pumps, piping, etc.; shop and business experience; desires responsible position, best of references.

325 Member, forty-three years of age, graduate M.E., experience as draftsman, chief draftsman, mechanical engineer, and chief designer of steam engines and compressors. Will accept position after February 1, 1910, with firm building or contemplating building this class of machinery.

326 Junior member, technical graduate, mechanical, six years experience, at present employed. Designing, estimating costs, inspecting and erecting with car-building company; assistant engineer with engineers and contractors on power and industrial plant construction. Would prefer connection from January 1, 1910, with engineering organization or manufacturer in New York city, as assistant engineer, assistant manager or sales engineer.

327 Member would like connection with firm, or individual manufacturer who is looking forward to gradually retiring from active oversight of business and desires some one to assume the responsibility. Possess a well rounded experience in shop work and designing, and as general superintendent covering all sides of a business. Personal interview preferred.

328 Junior member, graduate mechanical engineer, specialist on gas engines and refrigeration, would like to become associated with an established consulting engineer, or with a firm needing an up-to-date man.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ADAMS, Kilburn E. (Junior, 1908), Mech. Engr., Boston & Albany R. R., Rm. 372, South Sta., Boston, and *for mail*, 123 Oxford St., North Cambridge, Mass.

ADAMS, Thomas D. (Junior, 1906), Werner & Pfleiderer, and *for mail*, 619 Emerson St., Saginaw, Mich.

ALEXANDER, Edward E. (Associate, 1908), Ch. Draftsman, Am. Loco. Co. Cooke Wks., and *for mail*, 830 E. 23d St., Paterson, N. J.

ANDERSON, Harry Warfield (Associate, 1907), Anderson-Kent Co., 1030 Candler Bldg., and *for mail*, Owens Apts., 5 E. 3d St., Atlanta, Ga.

ARD, Charles Edgar (1908), Mgr., Christopher, Ard & Co., Engrs. and Contrs., Starkville, Miss.

BAGGALEY, Ralph (Associate, 1891), Life Member; 5th Ave. and Emerson St., Pittsburg, Pa.

BANTA, Earle J. (1907), Cincinnati Equipment Co., Cincinnati, O.

BARNES, Charles B. (1905; 1908), Mech. Engr., Holabird & Roche, Archts., Monadnock Bldg., and *for mail*, 1400 E. 53d St., Chicago, Ill.

BEECHER, J. F. (Associate, 1908), Draftsman, Pa. Steel Co., and *for mail*, 310 N. 2d St., Harrisburg, Pa.

BIGELOW, Charles H. (1904), with Chas. T. Main, Mill Engr., 45 Milk St., Boston, and *for mail*, 46 Calhaun Ave., Everett, Mass.

BLANCHARD, Arthur S. (Associate, 1909), Asst. Genl. Mgr., Birdsboro Steel Fdy. & Mch. Co., Birdsboro, Pa.

BRIDGE, James W. (Associate, 1905), Boswell, Pa.

BROWN, Robt. S. (1891; 1904), Secy., New Britain Mch. Co., and *for mail*, 16 Forest St., New Britain, Conn.

BURGESS, Edward W. (Junior, 1908), Metzger Motor Car Co., and *for mail*, 147 Milwaukee Ave. E., Detroit, Mich.

CHAMBERLAIN, Geo. E. (1907), Pres., Lewell Mfg. Co., 1402 Mich. Ave., Chicago, Ill.

CONLEE, George D. (Junior, 1906), Supt., Binghamton Gas Wks., 40 Chenango St., and *for mail*, 71 Carroll St., Binghamton, N. Y.

COX, Claude E. (Associate, 1907), H. E. Wilcox Motor Car Co., Minneapolis, Minn.

CRANE, William Edward (1887), Broadalbin, N. Y.

CRAWLEY, George E. (Junior, 1908), 548 W. 124th St., New York, N. Y.

DAUGHERTY, Frank (Junior, 1909), Cons. Engr., 2109 Chestnut St., Philadelphia, Pa.

DAVIS, Edwin Halsted (Junior, 1907), Ch. Draftsman, Davidson's Steam Pump Wks., and *for mail*, 256 Martense St., Brooklyn, N. Y.

EILERS, Karl Emrich (1890; 1904), Am. Smelting & Refining Co., 165 Broadway, and *for mail,* 320 Central Park W., New York, N. Y.

ENGLISH, Harry K. (Associate, 1908), 213 Glenwood Blvd., Schenectady, N. Y.

EYERMANN, Peter (1908), care of Am. Soc. M.E., 29 W. 39th St., New York, N. Y.

FITCH, Alfred Lyon (Associate, 1907), Asst. Supt., Union Wire Mattress Co., Blackhawk St., and Cherry Ave., and *for mail,* 1132 E. 45th St., Chicago, Ill.

FORSYTH, William (1883), Manager, 1888–1891; Mech. Engr., R.R. Age Gazette, 303 Dearborn St., and Windermere Hotel, Chicago, Ill.

FRITZ, Aime L. G. (Junior, 1907), Tee Square and Triangle Co., 30–32 Clinton St., Newark, N. J.

FROHWEIN, Richard W. (Junior, 1907), Pur. Agt., M. H. Treadwell Co., 140 Cedar St., New York, N. Y., and *for mail,* 431 Magee St., Elizabeth, N. J.

GARDNER, Horace C. (1904), Mgr. Constr. and Mech. Depts., Swift & Co., and *for mail,* Kenwood Hotel, Chicago, Ill.

GERRISH, William H. (1901), Supt. Soft Fibre Dept., Columbian Rope Co., and *for mail,* 164 W. Genesee St., Auburn, N. Y.

GIELE, Walter S. (Junior, 1908), Harrison Safety Boiler Wks., Philadelphia, Pa., and *for mail,* 3 Hamilton Park, New Brighton, S. I., N. Y.

GILLAN, Howard A. (Junior, 1907), 116 W. 102d St., New York, N. Y.

GODDARD, Arthur L. (1903), 1618 School St., Rockford, Ill.

GOWIE, William (1905), Emily & Warren Aves., Crafton, Pa.

GREEN, Chas. Henry (Junior, 1905), Member of Firm, M. A. Earl & Co., Carthage, Mo.

GROHMANN, Carl L. (1898), Mech. Engr., Pratt & Whitney Co., and *for mail,* 268 N. Oxford St., Hartford, Conn.

HAGERTY, Walter W. (Junior, 1905), 720-A Quincy St., Brooklyn, N. Y.

HALE, Robt. Sever (1894; 1897; 1899), Supt. Sales Dept., Edison Elec. Ill. Co., 39 Boylston St., Boston, Mass., and *for mail,* 1131 Franklin Ave., Wilkinsburg, Pa.

HAMILTON, Chester B., Jr. (Junior, 1909), Smith, Kerry & Chace, Cons. Engrs., and *for mail,* 43 Madison Ave., Toronto, Ont.

HELVEY, Clarence H. (Junior. 1905), Secy., Republic Motor Car Co., Hamilton, O.

HENDEE, Edward Thomas (Associate, 1908), Mgr. Mchy. Dept., Joseph T. Ryerson & Son, and *for mail,* 4143 Sheridan Rd., Chicago, Ill.

HENES, Louis G. (Junior, 1903), Mgr. Manning, Maxwell & Moore, Inc., Mgr., Commercial Acetylene Co., 247–249 Monadnock Bldg., San Francisco, Cal.

HOLMES, Walter G. (1897; 1907), Ch. Draftsman, Linderman Mch. Co., Muskegon, Mich.

HOWARD, Chas. Alton (Junior, 1907), E. W. Bliss Co., Adams and Plymouth Sts., Brooklyn, and *for mail,* 180 W. 76th St., New York, N. Y.

KEIL, Gustave B. (1908), Mech. Engr., 4109 N. Paulina St., Chicago, Ill.

KENT, William (1880), Manager, 1885–1888; V. P., 1888–1890; Rm. 1203, Monadnock Bldg., Chicago, Ill.

KNOWLTON, Frederic K. (Junior, 1904), V. P. and Secy., M. D. Knowlton Co., Rochester, and *for mail,* The Pines, East Ave., Pittsford, N. Y.

KREBS, A. Sonnin (1901; Associate, 1905), Mech. Engr., 1368 Gilpin St., Denver, Colo.

LARKIN, Everett P. (Junior, 1906), Bridgeport Brass Co., and *for mail*, 255 William St., Bridgeport, Conn.

LATTIN, Judson (1891), Supt., Internatl. Harvester Co. of Canada, Ltd., Sherman Ave., and 106 Ontario Ave., Hamilton, Ont.

McMULLEN, Vincent E. (Associate, 1907), Mech. Engr. in charge Exp. Wks., Fairbanks, Morse Mfg. Co., and *for mail*, 1010 Prairie Ave., Beloit, Wis.

MANTON, Arthur W. (1908), Murray Hill, Flushing, L. I., N. Y.

OWENS, Robert B. (Associate, 1892), Southern Power Co., Trust Bldg., Charlotte, N. C.

PAYSON, T. Elliott (Associate, 1906), Supt., Edengraph Mfg. Co., 135 W. 3d St., New York, N. Y., and *for mail*, 218 Clerk St., Jersey City, N. J.

PINNER, Seymour W. (Junior, 1909), Instr., Univ. of Mich., and *for mail*, 724 S. Ingalls St., Ann Arbor, Mich.

PUCHTA, Edward (1909), Asst. Supt., Western Elec. Co., 48th Ave. and W. 24th St., and *for mail*, 4739 Sheridan Rd., Chicago, Ill.

PULMAN, Thomas Chas. (1908), 153 Queen Victoria St., London, England.

RICHTER, Arthur Wm. (Junior, 1892), Univ. of Montana, Missoula, Mont.

RITCHIE, Francis P. (Associate, 1908), 32 Sussex Ave., Montreal, P. Q.

ROSE, William H. (Junior, 1901), 325 W. 93d St., New York, N. Y.

SALTZMAN, Auguste L. (1908), Charge Drafting Dept., Walter Scott & Co., and *for mail*, 605 Madison Ave., Plainfield, N. J.

SCHMIDT, Charles R. (1895), V. P., Cent. Fdy. Co., 37 Wall St., New York, N. Y., and *for mail*, 200 E. 24th St., Baltimore, Md.

SMART, Richard Addison (1894; 1900; 1906), Wks. Mgr., Oliver Chilled Plow Wks., South Bend, Ind.

SMEAD, William H. (Junior, 1906), Genl. Fire Extinguisher Co., Warren, O.

SMITH, Edward S. (Junior, 1909), Instr., Univ. of Va., and *for mail*, P. O. Box 172, University, Va.

STEBBINS, Theodore (1903), 14–16 Church St., New York, N. Y.

STONE, Mason A., Jr. (Junior, 1907), Engrg. Dept., Tide Water Oil Co., Bayonne, N. J., and *for mail*, 20 E. 35th St., New York, N. Y.

STURGESS, John (1901), Western Rep., Platt Iron Wks. Co., and 17 Rockwood Ave., Dayton, O.

TADDIKEN, J. F., Jr. (Junior, 1907), Am. Beet Sugar Co., Rocky Ford, Colo.

TAYLOR, John W. (Junior, 1909), Asst. Supt., Russell Eng. Co., and *for mail*, 88 3d St., Massillon, O.

TOLTZ, Max E. R. (1904), Manistee & Grand Rapids R. R. Co., 702 Manhattan Bldg., St. Paul, Minn.

WETMORE, Charles P. (1901), 1316 Carmen Ave., Chicago, Ill.

WHITEHURST, Herbert C. (Junior, 1908), Mgr. Evans, Almirall & Co., 10th and Byrd Sts., Richmond, Va.

YOUNG, William A. (1901; 1905; 1906), 522 S. Arch St., Alliance, O.

NEW MEMBERS

JACKSON, F. W. (1909), Dist. Mgr., Harrisburg Fdy. & Mch. Wks., Continental Trust Bldg., Baltimore, Md.

KOENIG, Adolph G. (Associate, 1909), Member of Firm, Mortensen & Co., Engrs. and Contrs., 401 W. 24th St., New York, N. Y.

GAS POWER SECTION

CHANGES OF ADDRESS

ANDERSON, Harry Warfield (1909), Anderson-Kent Co., 1030 Candler Bldg., and *for mail*, Owens Apts., 5 E. 3d St., Atlanta, Ga.

CONLEE, George D. (1908), Supt., Binghamton Gas Wks., 40 Chenango St., and *for mail*, 71 Carroll St., Binghamton, N. Y.

CRAWLEY, George E. (1908), 548 W. 124th St., New York, N. Y.

ENGLISH, Harry K. (1909), 213 Glenwood Blvd., Schenectady, N. Y.

HOWARD, Chas. Alton (1908), E. W. Bliss Co., Adams and Plymouth Sts., Brooklyn, and *for mail*, 180 W. 76th St., New York, N. Y.

LUCKETT, Gustavus Tyler (Affiliate, 1908), Mgr. Piping Dept., M. W. Kellogg Co., 50 Church St., and *for mail*, 603 W. 146th St., New York, N. Y.

McMULLEN, Vincent E. (1908), Mech. Engr. in charge Exp. Wks., Fairbanks, Morse Mfg. Co., and *for mail*, 1010 Prairie Ave., Beloit, Wis.

MITKIEWICZ, R. S. de (Affiliate, 1908), Sales Engr., Alden Sampson Mfg. Co., 115 Broadway, and *for mail*, 214 W. 85th St., New York, N. Y.

SAGE, Darrow (Affiliate, 1908), Ch. Engr., J. C. P. H., Hudson & Manhattan R. R. Co., Jersey City and *for mail*, 20 Ivanhoe Terrace, East Orange N. J.

SAMPSON, Charles C. (Affiliate, 1909), Inspr., Gas Power Mchy., Ill. Steel Co., South Chicago, and *for mail*, 646 E. 73d St., Chicago, Ill.

STUDENT SECTION

CHANGES OF ADDRESS

BLUM, Joseph K. (Student, 1909), Hotel San Remo, 75th St. and Central Park, W., New York, N. Y.
BRAKMAN, John A. (Student, 1909), 271 W. 71st St., New York, N. Y.
COONRADT, Arthur C. (Student, 1909), 635 Longwood St., Rockford, Ill.
COYLE, J. F. (Student, 1909), 2218 E. 101st St., Cleveland, O.
HERRMANN, George A. (Student, 1909), Rm. 1720, Ry. Exchange Bldg., Chicago, Ill.
HOLLENBERGER, Theo. J. (Student, 1909), 259 S. Main St., Akron, O.
JANDA, Jas. F. (Student, 1909), 1001 S. 5th St., Champaign, Ill.
MONTAGUE, Charles E. (Student, 1909), 115 W. Castle St., Syracuse, N. Y.
SHULTS, L. J. (Student, 1909), 1860 S. Kedzie Ave., Chicago, Ill.
SPERRY, F. E. (Student, 1909), 583 Benton St., Aurora, Ill.
TORRANCE, C. Everett (Student, 1909), 638 Stewart Ave., Ithaca, N. Y.

NEW MEMBERS

LELAND STANFORD, JR., UNIVERSITY

BECKLEY, R. E. (Student, 1909), Stanford Univ., Cal.
BLEE, H. H. (Student, 1909), 214 Emerson St., Palo Alto, Cal.
BRASSY, L. P. (Student, 1909), Box 636, San José, Cal.
HERBERT, E. H. (Student, 1909), Los Altos, Cal.
MESTON, A. F. (Student, 1909). Stanford Univ., Cal.
NORWOOD, C. T. (Student, 1909), Stanford Univ., Cal.
STEINBECK, C. E. (Student, 1909), Kingman, Ariz.
WARREN, H. C. (Student, 1909), Stanford Univ., Cal.

UNIVERSITY OF ILLINOIS

DUNSHEATH, L. M. (Student, 1909), 509 S. 4th St., Champaign, Ill.
HEILMAN, H. C. (Student, 1909), 912 S. Nevada St., Urbana, Ill.
HUNTINGTON, C. S. (Student, 1909), 906 S. Fifth Ave., Champaign, Ill.
KREIDLER, D. W. (Student, 1909), 410 Chalmes St., Champaign, Ill.
KUPPATRICK, H. J. (Student, 1909), 501 E. Green St., Champaign, Ill.
LUND, J. (Student, 1909), 506 E. John St., Champaign, Ill.
SPONSEL, J. G. (Student, 1909), 304 E. Daniel St., Champaign, Ill.
WESTLAND, A. F. (Student, 1909), 1202 W. Main St., Urbana, Ill.

COMING MEETINGS

November and December

Secretaries or members of societies whose meetings are of interest to engineers are invited to send in their notices for publication in this department. Such notices should be in the editor's hands by the 18th of the month preceding the meeting.

ALABAMA LIGHT AND TRACTION ASSOCIATION
November 15, 16, annual convention, Birmingham. Secy., Lloyd Lyon, 158 Government St., Mobile.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
December 27, Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN CIVIC ASSOCIATION
November 15–19, Cincinnati, O. Secy., Richard B. Watrous, Harrisburg, Pa.

AMERICAN FEDERATION OF TEACHERS OF MATHEMATICS
December 28, 29, annual meeting, Baltimore, Md. Secy., C. R. Mann, University of Chicago.

AMERICAN INSTITUTE OF ARCHITECTS
December 14–16, annual convention, Washington, D. C. Secy., Glenn Brown, Octagon Bldg.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
December 8–10, annual meeting, Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN MATHEMATICAL SOCIETY
November 27, University of Missouri, Columbia, Mo., Southwestern Section. Secy., O. D. Kellogg, 411 Hitt St.

AMERICAN PHYSICAL SOCIETY
November 27, University of Illinois, Urbana, Ill. Secy., Ernest Merritt, Ithaca, N. Y.

AMERICAN RAILWAY ASSOCIATION
November 17, annual meeting, Chicago, Ill. Secy., W. F. Allen, 24 Park Pl., New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
November 17, Boston, Mass. December 7–10, annual meeting, 29 W. 39th St., New York. July 26–29, 1910, joint meeting with Institution of Mechanical Engineers, Great Britain. Secy., Calvin W. Rice, New York.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
December 28, 29, annual meeting, Ames, Ia. Secy., L. W. Chase, Univ. of Neb., Lincoln, Neb.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS
December 6, New York meeting. Secy. W. H. Ross, 154 Nassau St.

AMERICAN SOCIETY OF SWEDISH ENGINEERS
November 20, 271 Hicks St., Brooklyn, N, Y. Paper: Magnetic Separation of Iron Ores, N. V. Hansell. Secy., E. Hammerstrom.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUACTURERS
December 14, 15, annual meeting, New York. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

ASSOCIATION OF TRANSPORTATION AND CAR ACCOUNTING OFFICERS
December 14, 15, Chattanooga, Tenn. Secy., G. P. Conard, 24 Park Pl., New York.

BROOKLYN ENGINEERS' CLUB
November 18, December 2, 117 Remsen St., Brooklyn, N. Y. Papers: Pneumatic Foundations, T. K. Thomson, Mem.Am.Soc.M.E.; Steel Sheet Piling, A. R. Archer. Secy., Joseph Strachan.

CENTRAL ELECTRIC RAILWAY ASSOCIATION
November 18, Claypool Hotel, Indianapolis, Ind. Papers: A Centralized Testing Organization, J. G. Callan; Publicity, A. D. B. Van Zandt; The Claim Adjusters' Association, E. C. Carpenter; The Transportation and Traffic Association, J. B. Crawford. Secy., A. L. Neereamer.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
November 16, December 21, Prince George Hotel, Toronto. Papers: Gas Engines, their Origin and Commercial Use, D. M. Henderson; Gas Manufacture, C. G. Herring. Secy., C. J. Worth, Union Sta.

COLORADO SCIENTIFIC SOCIETY
December 18, annual meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

EASTERN ICE ASSOCIATION
November 18–20, New York.

EMPIRE STATE GAS AND ELECTRIC ASSOCIATION
November 17, 18, 29 W. 39th St., New York. Secy., C. H. B. Chapin.

ENGINEERS' CLUB OF PHILADELPHIA
November 20. Paper: Rating of Pitot Tubes for Use in Testing a Niagara Power Plant. Secy., W. P. Taylor.

ENGINEERS' CLUB OF ST. LOUIS
December 1, annual convention, 3817 Olive St. Secy., A. S. Langdorf, Washington University.

ENGINEERS' CLUB OF TORONTO
November 18. Paper: Facts and Figures Relating to Producer Plant Practice, M. Chapman. Secy., R. B. Wolsey.

FRANKLIN INSTITUTE
December 10, Witherspoon Hall, Philadelphia, Pa. Lecture: Perils of Peace, or A Safer America, W. H. Tolman.

MODERN SCIENCE CLUB
November 16, 23, 30, 125 S. Elliott Pl., Brooklyn, N. Y. Papers: Globe, Gate and Check Valves, Russell Bonnell; The Use of Incandescent Lamps in Illumination, B. F. Fisher, Jr.; Water Storage for Power in the Adirondacks, W. T. Donnelly, Mem.Am.Soc.M.E. Secy., J. A. Donnelly.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS
November 16, annnal meeting, Washington, D. C. Secy., M. S. Decker, Albany, N. Y.

NATIONAL CIVIC FEDERATION

November 22, 23, annual meeting, New York. Secy., D. L. Cease, Metropolitan Bldg.

NATIONAL COMMERCIAL GAS ASSOCIATION

December 12, 14, annual convention, Madison Square Garden, New York. Secy., L. S. Bigelow, Light Publishing Co., Willimantic, Conn.

NATIONAL GAS AND GASOLENE ENGINE ASSOCIATION

November 30, December 1, 2, LaSalle Hotel, Chicago, Ill. Secy., Albert Stritmatter, Cincinnati, O.

NATIONAL MUNICIPAL LEAGUE

November 15–19, Cincinnati, O. Secy., C. R. Woodruff, 121 S. Broad St., Philadelphia, Pa.

NATIONAL SOCIETY FOR PROMOTION OF INDUSTRIAL EDUCATION

December 1–3, annual convention, Milwaukee, Wis. Secy., J. C. Monaghan, 20 W. 44th St., New York.

NEW JERSEY SANITARY ASSOCIATION

December 3, 4, annual meeting, Laurel-in-the-Pines, Lakewood. Secy., J. A. Exton, 75 Beech St., Arlington.

NEW YORK RAILROAD CLUB

November 19, 29 W. 39th St. Paper: The Handling of Freight at Terminals, H. McI. Harding. Secy., H. D. Vought, 95 Liberty St.

OHIO SOCIETY MECHANICAL, ELECTRICAL AND STEAM ENGINEERS

November 19, 20, main annual meeting, Lima, O. Secy., David Gaehr, Schofield Bldg., Cleveland.

RICHMOND RAILROAD CLUB

December 13. Paper: Block Signals, Chas. Stephens. Secy., F. O. Robinson.

ROCHESTER ENGINEERING SOCIETY

December 10, annual meeting. Secy., John F. Skinner , 54 City Hall.

SHORT LINE RAILROAD ASSOCIATION

December 14, annual meeting, New York. Secy., J. N. Drake, 60 Wall St.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

November 18–19, general meeting, 29 West 39th St., New York. Papers: Applications of Electricity to the Propulsion of Naval Vessels, W. L. R. Emmet, Mem.Am.Soc.M.E.; The Producer-Gas Boat Marenging, H. L. Aldrich, Assoc.Mem.Am.Soc.M.E.; The Foreign Trade Merchant Marine, G. W. Dickie, Mem.Am.Soc.M.E.; Material-Handling Arrangements for Vessels on the Great Lakes, A. E. Brown, Mem.Am.Soc.M.E., etc. Secy., W. J. Baxter.

SOUTHERN AND SOUTHWESTERN RAILWAY CLUB

November 18, annual meeting, Candler Bldg., Atlanta, Ga. Papers on Oil Lamps, Front-End Arrangements, Draft-Rigging. Secy., A. J. Merrill, 218 Prudential Bldg.

SOUTHWESTERN ICE MANUFACTURERS' ASSOCIATION

November 16–18, San Antonio, Tex.

WASHINGTON SOCIETY OF ENGINEERS

November 24, anniversary celebration. Secy., Paul Bausch.

WESTERN SOCIETY OF ENGINEERS

November 20, December 1, 1735 Monadnock Blk., Chicago, Ill. Papers: The Panama Railroad, Ralph Budd; Compressed Air in Contract Work, M. W. Briseler; River and Harbor Improvements at Chicago and the Calumet, T. H. Rees.

MEETINGS TO BE HELD IN THE ENGINEERING BUILDING

Date November	Society	Secretary	Time
16	New York Telephone Society	T. H. Lawrence	8.00
17–18	Empire State Gas and Electric Asso	C. H. B. Chapin	All day
18–19	Naval Architects and Marine Engineers	W. J. Baxter	All day
19	New York Railroad Club	H. D. Vought	8.15
24	Municipal Engineers of City of New York	C. D. Pollock	8.15
December			
1	Wireless Institute	S. L. Williams	7.30
2	Blue Room Engineering Society	W. D. Sprague	8.00
4	Amer. Soc. Hungarian Engrs. and Archts.	Z. DeNemeth	8.30
7–10	The American Society Mech. Engineers	Calvin W. Rice	
9	Illuminating Engineering Society	P. S. Millar	8.00
10	American Institute of Electrical Engineers	R. W. Pope	8.00
17	New York Railroad Club	H. D. Vought	8.15
21	New York Telephone Society	T. H. Lawrence	8.00
22	Municipal Engineers of City of N. Y.	C. D. Pollock	8.15

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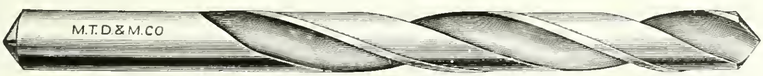

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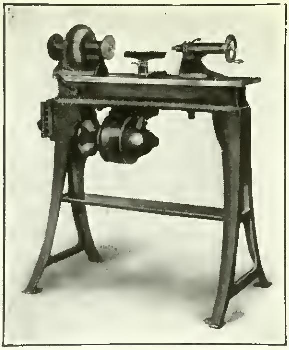

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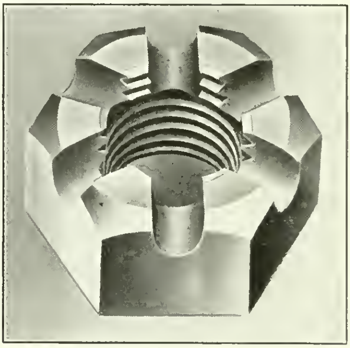

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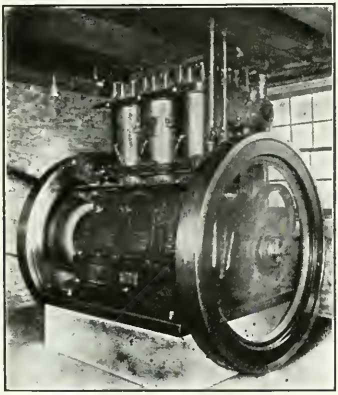

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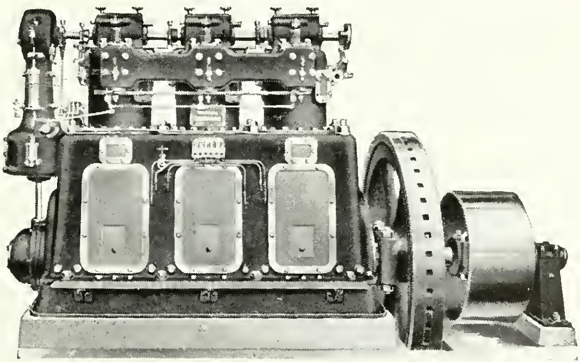

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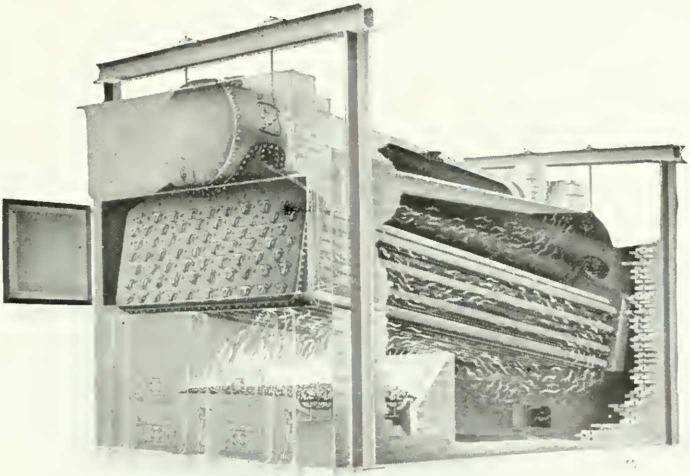

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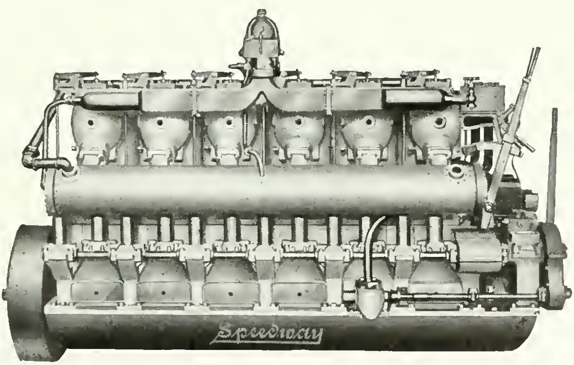

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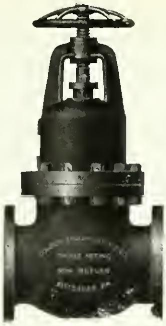

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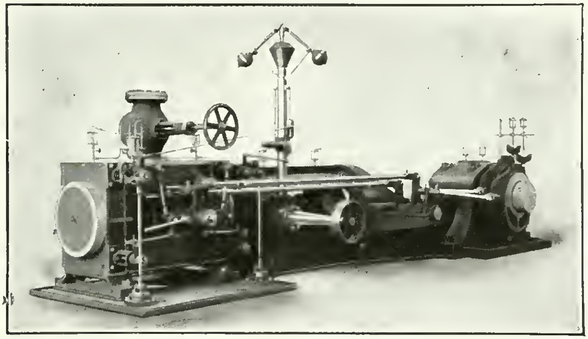

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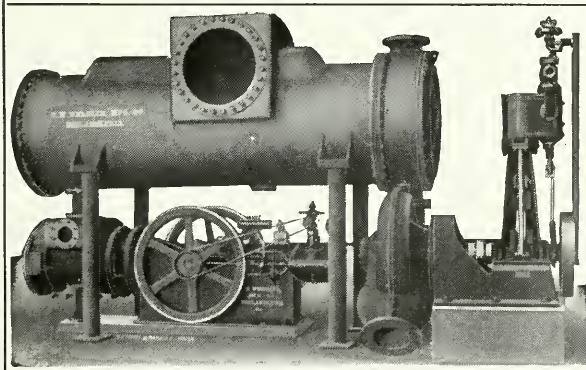

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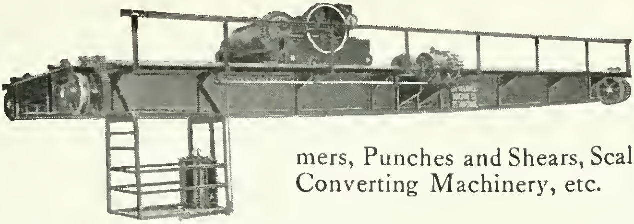

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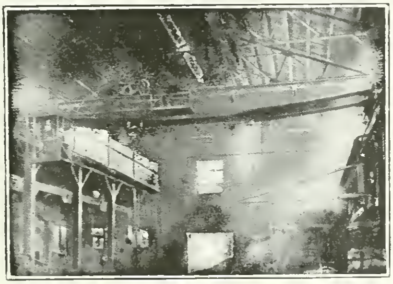

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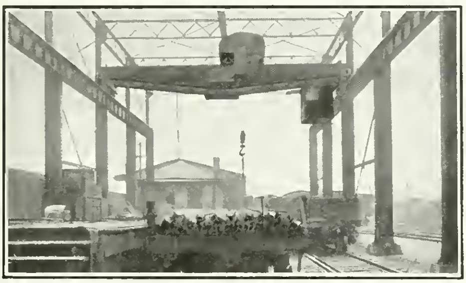

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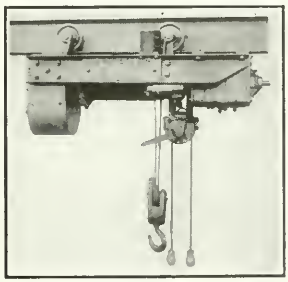

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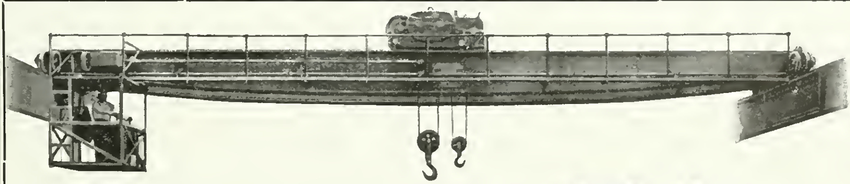

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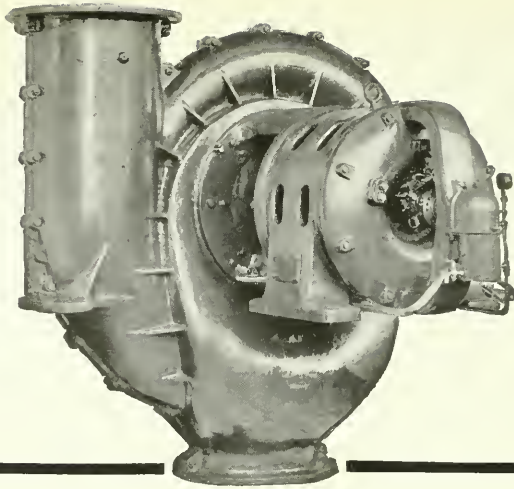

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THE

JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

DECEMBER 1909

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DECEMBER 1909 VOL. 31 No. 12

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OF

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THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 31 DECEMBER 1909 NUMBER 12

THE ANNUAL MEETING

The Thirtieth Annual Meeting of the Society will be held in the Engineering Societies' Building, 29 West 39th Street, New York, December 7 to 10.

The Meetings Committee, Willis E. Hall, *Chairman*, having entire charge of the professional program has arranged for four professional sessions at which papers are to be presented. On Wednesday morning following the regular business meeting important reports of the Gas Power Section will be presented for discussion. The sessions comprise a symposium on the Measurement of the Flow of Fluids with papers taking up the measurement of feed water, steam, air and gas. One session will be devoted to Steam Engineering subjects and another will be in charge of the Gas Power Section. For the latter session two papers of much interest have been assigned and additional reports not given at the time of the business meeting of the Society will be brought up for discussion.

ENTERTAINMENT

For the first time at an annual convention of the Society the social entertainment will be in charge of the members resident in and about New York under the immediate direction of a Local Committee appointed by them of which William D. Hoxie is Chairman. For Wednesday afternoon an excursion is planned which the members and guests will be asked to attend in a body and during the balance of the time there will be opportunities for smaller parties to visit places of interest.

Special efforts will be made to extend hospitality to out-of-town members and ladies and to promote an atmosphere of sociability which will facilitate the forming of friendships, the most important opportunity of the convention.

A Ladies' Reception Committee will arrange for the entertainment of the ladies in a manner similar to that of last year.

RECEPTIONS AND EVENING MEETINGS

At the opening session on Tuesday evening will be the introduction of the new President and the reading of the President's address, followed by a social gathering. On Wednesday evening there will be a lecture of unusual interest upon the Development of Agricultural Machinery by L. W. Ellis of the Bureau of Plant Industry of the Agricultural Department, Washington, D. C. He has at his disposal the information and photographs for slides that have been acquired by the Agricultural Department, showing the wonderful resources of the country on the great farms of the West, and he will dwell very largely on the development of the machinery which has kept pace with it and in which all engineers are interested.

On Thursday evening will be the reception, which will be held in the grand ballroom of the Hotel Astor. Boxes in the balcony will be available for members and guests who wish to attend and not participate in the dancing.

HEADQUARTERS

The headquarters will be established in the foyer on the first floor of the Engineering Societies' Building. Members and guests are requested to register immediately upon their arrival and receive a badge and program. Railroad certificates should be presented at that time for validation. A writing room will be provided on the first floor opposite the entrance fully equipped for the use of members. There is also a telephone exchange with several booths on the first floor adjoining the elevators, providing ample facilities for quick service.

MEMBERS REGISTER

Two editions of the printed Members Register will be issued. The first will include the names of those registered before 9 p.m. Tuesday, and will be distributed at the morning session on Wednesday. The second edition will contain the names of those registered before 10 p.m. on Wednesday. It will be distributed at the morning session on Thursday.

PROGRAM[1]

NEW YORK, DECEMBER 7–10, 1909

OPENING SESSION

Tuesday, December 7, 8.30 p.m., Auditorium

The President's Address.

Report of tellers of election of officers.

Introduction of the President-elect.

Reception by the President and President-elect, with their ladies, to the Membership of the Society, their ladies and friends, in the rooms of the Society. All are invited.

Music and refreshments.

Col. E. D. Meier, Chairman Sub-Committee in charge of President's Reception.

BUSINESS MEETING

Wednesday, December 8, 9.30 a.m., Auditorium

Annual business meeting. Reports of the Council, tellers of election of membership, standing and special committees and Gas Power Section. Amendments to the Constitution. New business may be presented at this session.

A luncheon will be served to the Membership and guests, on the fifth floor of the building, at 1.00 p.m. Cards may be obtained at the registration desk from the Sub-Committee in charge.

Wednesday afternoon

Excursion to points of engineering interest. Mr. Hosea Webster Chairman Sub-Committee on Excursions.

LECTURE

Wednesday, 8.15 p.m., Auditorium

Lecture by Mr. L. W. Ellis on the Development of Agricultural Machinery. Illustrated with lantern views.

PROFESSIONAL SESSIONS

Thursday, December 9, 9.30 a.m., Auditorium

MEASUREMENT OF THE FLOW OF FLUIDS

TESTS ON A VENTURI METER FOR BOILER FEED, by Chas. M. Allen.

THE PITOT TUBE AS A STEAM METER, Geo. F. Gebhardt.

[1] Subject to revision

All professional meetings of the Society will be called to order at the time specified on the program.

Efficiency Tests of Steam Nozzles, F. H. Sibley and T. S. Kemble

An Electric Gas Meter, C. C. Thomas.

A luncheon will be served to the Membership and guests, on the fifth floor at 1.00 p.m. Cards may be obtained at the registration desk from the Sub-Committee in charge.

Thursday, 2 p.m., Auditorium

STEAM ENGINEERING

Tan Bark as a Boiler Fuel, David M. Myers.

Cooling Towers for Steam and Gas Power Plants, J. R. Bibbins.

Some Studies in Rolling Mill Engines, W. P. Caine.

An Experience with Leaky Vertical Fire Tube Boilers, F. W. Dean.

The Best Form of Longitudinal Joint for Boilers, F. W. Dean.

Thursday, 2 p.m., Lecture Hall, 6th floor

GAS POWER SECTION

Business meeting and election of officers

Testing Suction Gas Producers with a Koerting Ejector C. M. Garland, A. P. Kratz.

Bituminous Producers, J. R. Bibbins.

RECEPTION

Thursday, 9 p.m., Hotel Astor

Reception by the Members of New York and vicinity to the Officers and Membership of the Society, their ladies and guests, at the Hotel Astor.

Dancing and refreshments.

Cards will be required, obtainable at the Registration desk, from the Sub-Committee in charge.

Prof. Arthur L. Williston, Chairman Sub-Committee in charge of the Reception.

PROFESSIONAL SESSION

Friday, December 10, 9.30 a.m., 6th floor

The Bucyrus Locomotive Pile Driver, Walter Ferris.

Line Shaft Efficiency, Mechanical and Economic, Henry Hess.

Pump Valves and Valves Areas, A. F. Nagle.

A Report on Cast-Iron Test Bars, A. F. Nagle.

RAILROAD TRANSPORTATION NOTICE

For members and guests attending the Annual Meeting in New York, December 7-10, 1909, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 3 and 9 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has no certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival, present your certificate to S. Edgar Whitaker at headquarters, with 25 cents for validation. A certificate cannot be validated after December 10.

d An agent of the Trunk Line Association will validate certificates December 8, 9 and 10. No refund will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for a certificate, and to turn it in at headquarters. Even though you may not use it this will help others to secure the reduced rate.

f If the certificate is validated, a return ticket to the destination can be purchased, up to December 14, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlotteville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

New England Passenger Association, except via Bangor and Aroostook R. R., Rutland R. R., N. Y. O. & W. R. R., Eastern Steamship Co. and Metropolitan Steamship Co.

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver; Iowa, Minnesota and Wisconsin. Missouri north of a line through Kansas, Jefferson City and St. Louis; Illinois north of a line from Chicago through Peoria to Keokuk.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

OTHER COMING MEETINGS OF THE SOCIETY

At the meeting of the Society to be held in Boston on December 17, at the Edison Auditorium, the following papers will be presented, forming a symposium on the Effect of Superheated Steam on Cast Iron and Steel:

Cast-Iron Fittings for Superheated Steam, by Prof. I. N. Hollis.

The Effect of Superheated Steam on the Strength of Cast Iron, Gun Iron, and Steel, by Prof. E. F. Miller.

Cast-Iron Valves and Fittings for Superheated Steam, by Arthur S. Mann.

A meeting of the Society will be held at St. Louis, December 11.

RECENT MEETINGS OF THE SOCIETY

BOSTON, OCTOBER 20

On Wednesday evening, October 20, a meeting of the Society was held at Boston with the Boston Society of Civil Engineers, in Tremont Temple. A paper on the Strength of Reinforced Concrete Beams was presented by Prof. Gaetano Lanza, followed by an interesting discussion in which the following took part; Vice-President Chas. T. Main, of the Boston Society of Civil Engineers, F. Sumner Hinds Desmond FitzGerald, Robert L. Read, Prof. C. M. Spofford, Henry F. Bryant, Prof. Geo. F. Swain, Rolf R. Newman. Contributed discussion was also presented by J. R. Worcester and Harry E. Sawtelle.

NEW YORK, NOVEMBER 9

At the meeting of the Society at New York on November 9, Professor Lanza presented his paper on Stresses in Reinforced Concrete Beams, and Professor Rautenstrauch, his paper on Design of Curved Machine Members. The discussion on both papers proved of great value, the lantern slides shown in the discussion of Professor Lanza's paper adding much to its interest. A number of authorities on reinforced concrete design and construction had expressed a desire to discuss Professor Lanza's paper and much valuable information was brought out regarding the present state of the art. Those discussing

the paper were Sanford E. Thompson, E. P. Goodrich, Professor Rautenstrauch, Prof. W. H. Burr, B. H. Davis, of the Lackawanna Railroad, who showed slides of a number of concrete arches in railroad work; C. B. Grady of the New York Edison Company, who showed slides of beams and floor slabs under test; F. B. Gilbreth, who showed slides of the longest concrete beam of a rectangular section ever built in a roof, as well as other beams which had successfully passed through the fire and earthquake of the San Francisco disaster. Contributed discussions by Prof. J. C. Ostrup, E. L. Heidenreich, and C. E. Houghton were also presented. Professor Rautenstrauch's paper was discussed by a number of authorities on machine tool design, as follows: Professor Lanza, Chas. R. Gabriel, George R. Henderson, Professor Burr, Herman A. Knoener, and Carl G. Barth. Those submitting written discussions were: C. E. Houghton, A. L. Campbell, H. Gansslen, F. I. Ellis, E. J. Loring and John S. Myers.

MEETING OF THE COUNCIL

A meeting of the Council was called to order at 3 p.m., November 9, 1909, in the rooms of the Society, Jesse M. Smith, President, presiding. There were present: Messrs. Miller, Hunt, Gantt, Swasey, Carpenter, Stott, Riker, Wiley, Moultrop, Breckenridge and the Secretary. Regrets were received from George M. Bond.

The Secretary reported the death of Lewis C. Grover.

EXECUTIVE COMMITTEE

The Chairman reported the forwarding of the formal acceptance of the invitation of the Institution of Mechanical Engineers and that the invitation and acceptance were to be printed in a circular letter soon to be sent to the entire membership, together with a reply postal card, to ascertain how many members were going or hoped to go to England next year, as well as those who know they cannot go.

AMENDMENTS TO BY-LAWS AND RULES

Notice of proposed amendment to By-Law B 13–36–34 was given.

Voted: That the matter of amendment to C–18 and B–18 be referred to the Finance Committee.

Voted: To approve the following amendment to Rule 4.

R–4 Each paper which has been accepted by the Committee on Meetings for presentation at any meeting of the Society shall be published in The Journal at least seven days in advance of that meeting and in the form in which it has been

accepted by that Committee, and that paper shall also be distributed in pamphlet form at that meeting. A paper received too late for such distribution shall only be accepted for presentation at that meeting by unanimous consent of the Committee on Meetings, and shall if so accepted be published in a subsequent issue of The Journal. A member may by letter signify his intention to discuss any of the papers and unless otherwise directed by the presiding officer priority in debate shall be given in the order of the receipt by the Secretary of such notification.

MACHINE SHOP SECTION

Resolutions of the Committee were presented, expressing the accord and sympathy of the Council with those seeking to give special prominence to papers and discussions on the machine shop and related topics and its approval of a policy whereby the individual activity of members interested in special topics of practice or discussion may be enlisted. To this end the Council will favor the creation of sub-committees of members of the Society, under the general direction of the Meetings Committee, to assist that Committee in procuring papers, the holding of meetings for their discussion, and the stimulation of activity and interest along such special lines.

Voted: That the report of the Executive Committee with respect to a Machine Shop Section be adopted and referred to the Meetings Committee, for their recommendations.

STUDENT BRANCHES AND RULES

Voted: To adopt the Committee's report on Student Branches, containing the following resolutions:

That the Secretary be authorized by Council to take all necessary preliminary steps when the application for a student branch comes from any university, college or technical school authorized by charter to give degrees in engineering or applied science and which has a member or members of the Society in its faculty, who shall join in making such application. Such a Student Branch must have an enrollment of at least fifteen students; must make application to the Council on a blank provided by the Secretary, this blank to receive the signature of approval of said member of the faculty and also that of the dean or executive head of the institution; and must file with the Secretary a copy of its Constitution and By-Laws, together with an agreement to comply with the rules and requirements of the Society during the existence of their relationship.

Resolved: That the printed list of Committees in the Year Book contain a Committee on Student Branches and that until further action Prof. F. R. Hutton, Honorary Secretary, be appointed such Committee.

The Executive Committee shall have power to direct the Secretary to organize such a Student Branch when the foregoing requirements have been complied with, and shall report such action to the Council.

Voted: That the Council approve the applications of the following student bodies, as recommended by the Executive Committee, to become Affiliate Branches of the Society: University of Illinois, Pennsylvania State College, New York University, Massachusetts Institute of Technology, University of Cincinnati, University of Wisconsin, and Columbia University.

MEETINGS COMMITTEE

The Secretary reported that the Council had passed resolutions, authorizing the Meetings Committee to establish meetings in different cities, on the same basis as those held monthly in New York, but subject to the approval of the Executive Committee and Council.

The question of the necessity of this approval in each case was considered and it was

Voted: That the Council approve the meetings that have already been held in cities other than New York, and which have already been approved by the Executive Committee; and further

Voted: That the whole subject of all monthly meetings of the Society be referred to the Committee on Meetings, with full power.

PUBLICATION COMMITTEE

The report of the Publication Committee with respect to the Year Book was adopted, with amendments, as follows:

Voted: To publish the Year Book once a year in February; that the next issue be the standard club-book size, to be issued with complete alphabetical list and with abbreviated geographical list, giving the minimum information necessary in order to address a man at his firm, or his home in case he has no business address. Make-up of book to be changed to the list of officers and Standing Committees first, list of members, and finally Constitution and By-Laws; including a picture of the building.

It was further

Voted: That the design of the cover of the present Year Book be adopted as the style of the outside cover of all succeeding Year Books, but reduced in size.

FINANCE COMMITTEE

The Finance Committee recommended to the Council that, in the absence of the President or the Treasurer, one of the Vice-Presidents be appointed Assistant Treasurer, to sign checks duly authorized by the Finance Committee. It was

Voted: To defer the appointment of an Assistant Treasurer to the first meeting of the Council under the new administration.

ANNUAL REPORTS OF STANDING COMMITTEES

The Secretary presented annual reports of the Standing Committees The reports of the Finance Committee and of the Auditors were adopted and ordered printed in The Journal. It was further

Voted: That the reports of all the Standing Committees be published in The Journal. The meeting adjourned.

ACCESSIONS TO THE LIBRARY

The list of accessions to the library which is published in each issue of The Journal includes only those volumes or pamphlets which have been added by gift, exchange or purchase to the individual library of The American Society of Mechanical Engineers, included in the United Engineering Library. A list of the accessions to the libraries of the American Institute of Mining Engineers and the American Institute of Electrical Engineers, also included in the joint library, may be secured upon request of the Secretary of the Society.

EDWIN REYNOLDS, PRESIDENT AM.SOC.ME., 1902

MR. REYNOLDS IS SEATED AT THE DESK JUST PRESENTED BY MRS. REYNOLDS TO THE SOCIETY

EDWIN REYNOLDS DESK

The Society has just received as an addition to the furniture of its rooms a very valuable desk of extraordinarily fine workmanship, which belonged to Edwin Reynolds, President of the Society for 1902. The desk was presented to the Society by Mrs. Reynolds on her husband's death, February 19, 1909, and will be kept in the rooms for the use of each successive president.

The desk is a roll-top desk of solid mahogany, natural finish, six feet long and high, and elaborately and beautifully carved. It was made in Antwerp and took several prizes for design and workmanship abroad and in America. Its value is probably $1500.

The desk was presented to Mr. Reynolds on the occasion of his seventieth birthday by his associates of the Edward F. Allis Company, afterwards the Allis-Chalmers Company, of Milwaukee, Wis., of which he was then a vice-president and superintendent. Accompanying the gifts was the following memorial, which will be preserved with the desk.

Milwaukee, Wisconsin
March 23, 1901.

Mr. Edwin Reynolds, 2d Vice Pres. & Supt. of The Edward P. Allis Company,

It is our pleasure in behalf of the Employees of this Company which includes all from the President to the latest Apprentice to present to you on this your 70th Birthday this Desk, together with the Chairs, Table and Rug which complete the furnishing of your office.

The founder of this business, Edward P. Allis, started its career in 1860 with 35 employees. When you became associated with it in 1877 there were about 300 workers within its walls. Today after nearly a quarter century of your able superintendency, you see around you 2500 earnest strivers after its success, and all united in wishing you God speed in whatever the future may bring to you.

In making the presentation it is the sincere desire and earnest wish of all that these tokens of our good will may occupy their present quarters with your honored self enjoying them for long years to come, but should your best interest require that your labors be put forth in another field, or that you should take a well deserved rest, these mementoes accompanying you, will still be a daily reminder of the friendship and esteem of your co-workers, who these many years have labored and wrought with you in the upbuilding of these works.

That the years of your life may only be numbered when their usefulness and enjoyment is completed, is the sincere and earnest wish of all

The Committee.

REPORTS ON STANDING COMMITTEES TO THE COUNCIL

REPORT OF THE FINANCE COMMITTEE

The Committee submits the statements of the financial condition of the Society, together with the report of Peirce, Struss & Co., of New York, certified public accountants, who have audited the books and accounts.

PEIRCE STRUSS & CO.
CERTIFIED PUBLIC ACCOUNTANTS
37 Wall Street, New York

November 8, 1909

MR. ARTHUR M. WAITT,
CHAIRMAN FINANCE COMMITTEE

Dear Sir:

In accordance with your instructions, we have audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1909.

The results of this examination are presented in three exhibits, attached hereto, as follows:

Exhibit A Balance Sheet, September 30, 1909.

Exhibit B Income and Expenses; based on Cash receipts for year ended September 30, 1909.

Exhibit C Receipts and Disbursements for year ended September 30, 1909.

We beg to present, attached hereto, our certificate to the aforesaid exhibits.

Respectfully submitted,
PEIRCE, STRUSS & CO.
Certified Public Accountants

PEIRCE, STRUSS & CO.
CERTIFIED PUBLIC ACCOUNTANTS
37 Wall Street, New York

November 8, 1909

MR. ARTHUR M. WAITT,
CHAIRMAN FINANCE COMMITTEE

Dear Sir:

Having audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1909, we hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of September 30, 1909, and that the attached statements of Income and Expenses, and Cash Receipts and Disbursements, are correct.

PEIRCE, STRUSS & CO.
Certified Public Accountants

EXHIBIT A

Balance Sheet, September 30, 1909

ASSETS

Equity in Societies Building (25 to 33 West 39th Street)	$353 346.62	
Equity, one-third cost of land (25 to 33 West 39th Street)	180 000.00	
		$533 346.62
Library Books	$13 700.60	
Furniture and Fixtures	2 966.96	
		16 667.56
New York City 3½ % Bonds 1954, Par, $35,000	$30 925.00	
Cash in Bank representing Trust Funds	12 918.39	
		43 843.39
Stores including plates and finished publications		11 600.00
Cash in Bank for general purposes	$7 444.83	
Petty Cash on hand	250.00	
		7 694.83
Accounts Receivable		
Membership dues	$4 924.50	
Initiation fees	285.00	
Sale of publications, advertising, etc	4 334.55	
		9 544.05
Advances account of land subscription fund		7 960.94
Advanced payments		2 214.15
Total assets		$632 871.54

LIABILITIES

United Engineering Society (for cost of land)		$81 000.00
Funds		
Life membership Fund	$35 151.07	
Library Development Fund	4 902.71	
Weeks Legacy Fund	1 957.00	
Land Fund Subscriptions	1 227.88	
Robert H. Thurston Memorial Fund	399.13	
Subscriptions to Annual Meeting	205.60	
		43 843.39
Current Accounts Payable		11 163.00
Membership dues paid in advance	$494.50	
Initiation fees paid in advance	50.00	
		544.50

Initiation fees uncollected	$285.00
Reserve (Initiation fees)	24 596.97
Surplus in property and accounts receivable	471 438.68
Total Liabilities	$632 871.54

EXHIBIT B

Income and Expenses based on Cash Receipts for Year Ended September 30, 1909

INCOME

Membership dues, current	$50 273.79	
Membership dues, arrears	2 355.00	
Sales gross receipts	8 847.39	
Advertising receipts	11 997.50	
Interest and Discount	1 234.68	
Reserve Fund, 10%	3 010.77	
		$77 719.13

EXPENSES

Finance Committee Office Administration including Salaries	$19 971.91	
Finance, United Engineering Society Assessments	6 000.00	
Finance, miscellaneous	983.56	
		$26 955.47
Membership Committee		2 392.36
Increase of Membership Committee		147.94
House Committee[1]		1 192.43
Library Committee		2 699.17
Meetings Committee		
Annual Meeting	$2 074.24	
Spring Meeting	1 410.52	
Monthly Meetings	2 278.19	5 762.95
Publication Committee		
Advertising Section The Journal	$7 026.06	
Journal, except Advertising	13 134.80	
Pocket List	1 599.59	
Revises	523.93	
Transactions, Vol. 30	6 533.87	
Year Book	1 401.30	
History	43.65	
		30 263.20

[1] From Current Income	$1192.43
Reserve Fund	2500.00
Total Expenses	3692.43

Research Committee	$0.58	
Committee on Power Test	11.25	
Sales Expenditures	4 060.99	
		$73 486.34
Excess of Income over Expenses		4 232.79
		$77 719.13

EXHIBIT C

Receipts and Disbursements for Year Ended September 30, 1909

RECEIPTS

Membership dues	$50 832.70	
Initiation fees	6 460.00	
Membership dues and initiation fees paid in advance	551.00	
Sales of publications, badges, advertising, etc	20 833.25	
Subscriptions to Land Fund	3 251.00	
Subscriptions to Expense of Annual Meeting	2 188.00	
Interest	2 072.24	
John Fritz Medal	123.74	
Cash Exchanges per contra	575.92	
	$86 887.85	
Cash in Banks and on hand, September 30, 1908	13 708.98	
		$100 596.83

DISBURSEMENTS

Disbursements for general purposes	$76 167.69	
Interest on Mortgage on land	3 240.00	
Cash Exchanges per Contra	575.92	
	$79 983.61	
Cash in Banks and on hand, September 30, 1909	20 613.22	
		$100 596.83

The Committee also submits as called for by the By-Laws a detailed estimate of the probable income and expenditure of the Society for the Fiscal year ensuing. This estimate has been submitted to the careful consideration of each committee concerned and the Finance Committee has been assured in each instance that the appropriations asked for in the estimate include all needed expenditures to carry out the work of the different committees as now planned and authorized.

It will be noted that the Society is not being operated for profit, but that practically all of the money received is appropriated for the development of the Society's various interests, and to enable giving to each member a constantly increasing return for his membership dues.

ESTIMATE, 1909–1910

Current Income		Current Expenses	
Dues, Current	$52000	Finance Committee	$26000
Dues, Arrears	2000	Membership Committee	2400
Reserve Fund, 10 %	2800	Increase Memb. Committee	500
Sales gross receipts	5000	House Committee[1]	1150
Interest	800	Library Committee	2880
Advertising	21000	Meetings Committee	8050
		Publication Committee	34900
	$83600	Research Committee	500
		Executive Committee[2]	600
		Power Tests Committee	500
		Sales Expenditures	3000
			$80480
		Excess of income over expense	3120
			$83600

[1] In addition $3000, to be appropriated from the Reserve Fund for the House Committee for betterments for 1909-1910.

[2] The appropriation for the Executive Committee for the foreign meeting to be $3000, to be divided from Current Income at not less than $600 per year for a term of years until cancelled.

Especial attention of the Council is called to the fact that in connection with entering upon our occupancy of the present refined and dignified headquarters, a large sum was advanced from the Society's working capital, known as the Reserve to the Land and Building Fund from which fund by vote of the Council the interest on the mortgage for the land is paid. Admittedly the Society cannot afford to pay for the present headquarters out of its current income unless the Society is freed from debt; and it was with the understanding that sooner or later this debt would be raised, that the Society was justified and enabled to accept the gift from Mr. Carnegie. During the past year the total receipts to the Land and Building Fund have been practically used up for paying the interest on the mortgage, without decreasing the total of the mortgage to the extent of one dollar.

The Finance Committee observes that it has been the custom, by ruling of the Council, to take 10 per cent of the Reserve Fund each year to be applied to the payment of current expenses; and they recommend to the Council that this custom be discontinued, and that the total payments into the Society of initiation fees, which go to make up the Reserve Fund, shall remain in the Reserve, and that only by special vote of the Council shall money be expended from this Reserve.

The Finance Committee trusts that the time is opportune for the Land and Building Fund Committee to take steps during the coming year to raise a portion if not all of the indebtedness amounting to about $90,000.

It is highly desirable in view of plans for broadening the work of the Society that our income available for such extension of work be increased. The organization of our Society is such that the Finance Committee is charged solely with the responsibility of administering the Financial affairs of the Society as they find them and not to produce revenue. All the remaining activities of the Society are for the expenditure of revenue. The Finance Committee suggests therefore that it would be in keeping with good management if a special committee was appointed to consider the essential feature of the Society's broader life, viz: the income side, and to see that it is increased to provide for the reduction caused by the discontinuance of taking 10 per cent annually from the Reserve for operating expenses and to provide for a broader work in the future.

Respectfully submitted

Arthur M. Waitt, *Chairman*
Edward F. Schnuck
George J. Roberts
Robert M. Dixon
Waldo H. Marshall
Finance Committee

REPORT OF THE HOUSE COMMITTEE

The House Committee reports that it has endeavored to make the headquarters of the Society more attractive, by a rearrangement of the rooms and by additions to the furnishings.

When the Society entered its new headquarters nearly three years ago, provisional furnishings were purchased sufficient to carry on the business of the Society but with no attempt at decorative features.

The original plans of the rooms provided for a large reception hall which visitors enter from the elevators. In common with the other floors of the building this hall was open to the main stairway.

A partition cutting off this stairway and another partition separating the offices has converted this hall into an excellent reception room.

Sliding doors have been arranged so that the Council Room, the Library and the Secretary's office give the effect of one large and spacious room.

The walls have been retinted, and new rugs cover the floors. Comfortable furniture has been placed in the reception room. There will be portieres between the rooms, draperies at the windows, and more comfortable chairs and divans added to the library and Council chamber.

The Committee has aimed to make the rooms homelike and comfortable, to make a place which the members will use freely for their own convenience and for meeting other members or friends for social or business engagements.

In addition to the large rooms referred to, a small room is especially reserved where members may attend to their correspondence or hold private conferences.

Photographs of the Past-presidents have been placed on the walls of the Library and by order of the Council a similar portrait of each succeeding President will be added as he retires from office. Nameplates have been placed on the portraits, paintings and historical objects, and a very complete catalogue of all these objects of historical interest has been prepared. This catalogue represents the result of long and painstaking research on the part of Mr. Edward Van Winkle of our Committee.

Respectfully submitted,

Henry S. Loud, *Chairman*
W. C. Dickerman
B. V. Swenson
Francis Blossom
Edward Van Winkle
House Committee

REPORT OF THE LIBRARY COMMITTEE

During the past year further steps have been taken in the evolutionary process of administering the libraries of the American Institute of Mining Engineers, the American Institute of Electrical Engineers and that of our own Society, as far as practicable, as a unit.

This process has involved the development of a comprehensive plan whereby the library of each society maintains only books on subjects in which its membership is particularly interested, treating all other publications in its library as duplicates. To the American Institute of Mining Engineers have been assigned the subjects of mining engineering, geology, mineralogy, chemistry, metallurgy and a part of chemical technology. To the American Institute of Electri-

cal Engineers the subjects of electrical engineering, electricity, physics, mathematics and pure science; and to this Society the subjects of general engineering, railroad engineering, mechanical engineering, civil engineering and a part of chemical technology. This plan has given satisfaction as a temporary working basis enabling each organization to complete or supplement imperfect sets from the collections of the others.

During the year a union card catalogue has been established, covering the libraries of the three Founder Societies, which enables readers to find at a glance all the literature on any subject that may be contained in any of the libraries.

A Library Conference Committee, consisting of the Chairmen of the Library Committees of the three societies, has under consideration a further important step toward the unification of the three libraries, involving the organization of the library of the United Engineering Society, to which the three societies shall bear the same relation as do the Founder Societies in the holding of the United Engineering Societies building and property. Such a plan will enable gifts of books or periodicals not specifically designated for one society to be received and taken care of and it may eventually result in the purchase of books jointly in which the three Societies would have a common ownership. This plan avoids purchases in triplicate or duplicate and concentrates the purchasing power and extension of the library in a way that will be of undoubted advantage to all who may have occasion to consult a comprehensive library of engineering literature, covering all branches of the profession and having available promptly after publication all the important books.

It is probable that these improvements will necessitate the carrying out of the original building plans for the library, providing additional shelving in the library room proper, so that all of the volumes may be readily accessible.

The present status of the Library of The American Society of Mechanical Engineers is as follows:

The following titles have been catalogued to date:

Durfee library	570	vol.
A. S. M. E. library	7237	"
Withdrawal of duplicates (not accessioned)	800	"
Pamphlets	1339	"
Total	9946	"

The additions provided for 1908–1909 and included in the above are as follows:

By gift	168	vol.
By purchase	95	"
By binding of exchanges	197	"
Total accessions	460	"

Respectfully submitted,

J. W. Lieb, Jr., *Chairman*
C. L. Clarke
H. H. Suplee
Ambrose Swasey
Leonard Waldo
} *Library Committee*

REPORT OF THE MEETINGS COMMITTEE

To facilitate the work of the present Committee, and it is hoped, of succeeding committees, a record has been made of its policies and decisions, some of the more important of which are given below:

The policy of the Committee shall be:

1 Further condensation of papers by the elimination of all superfluous and irrelevant matter, or matter previously printed, and of such statements of fact as are of common knowledge in the profession.

2 The solicitation and selection of such papers, together with the plan of their presentation at meetings, as may make the Transactions a historical and up-to-date record of the progress of all branches of mechanical engineering.

3 The presentation of a subject, whenever possible, in such a way as best to permit of a general and thorough discussion; and to this end to extend invitations to those, whether members or otherwise, whose experience has been such as to bring out the most valuable discussion of the subject.

4 At the Annual and Semi-Annual Meetings, a reduction, when possible, of the number of professional sessions, and of the number of papers assigned thereto in order that more opportunity may be given for satisfactory discussion and for social intercourse between the members. It is the opinion of the Committee that the professional sessions heretofore have been too crowded.

5 For the sake of uniformity, the adoption of a few rules for the guidance of authors, these to be based on the experience of the Committee and of the editorial department of the Society, and to offer a review of the rules governing similar organizations.

6 The adoption of rules tending towards greater uniformity in the actions of the Commitee; these rules to be such only as concern actions within the jurisdiction of the Committee and subject to such exceptions as in the opinion of the Committee may seem desirable.

During the past year, the Committee has submitted to the Council a number of suggestions relative to changes in some of the methods of conducting such affairs of the Society as relate to the Meetings Committee. All of these, with slight modifications, have been accepted and endorsed by the Council and so far as possible placed in operation.

The selection of a local committee to take charge of all entertainment, apart from the professional sessions, was tried at the last Annual Meeting with satisfactory results, which we believe long-established practice will make even better. This is creating greater interest among the local members, and a feeling of some responsibility for the entertainment of the visiting members, and places the Annual Meeting upon the same basis as the Spring Meeting, thereby eliminating what has been heretofore a somewhat inconsistent situation. The Social and Entertainment Committee will for the first time this year collect and disburse the fund for this purpose, which will be kept separate and apart from the funds of the Society. This phase of the arrangement cannot be otherwise than satisfactory.

The resolution of the Committee submitted to the Council, relative to meetings in mid-season in cities other than New York, was put into operation immediately upon approval by the Council. In the opinion of the Committee, this movement is progressing very satisfactorily and seems to be assuming a natural, healthy growth. The object of the resolution is outlined in The Journal for June 1909, pp. 17–19. Successful meetings were held at Boston, April 16, June 11, October 20, and November 17; and at St. Louis, April 10, May 15, October 16, and November 13. This movement, as was desired and anticipated, is bringing before the Society much valuable material in the form of papers and especially of discussion that would otherwise be inaccessible to the members. It has resulted in an exchange of papers, which promises to become more extensive in the future.

The Council's amendment to the Committee's resolution, "subject to the approval of the Council," we find from experience to be cumbersome. To facilitate these meetings, the Committee must act promptly upon request from members residing in places other than New York. With the appropriations for these meetings decided upon the Committee urges that the Council modify its instructions to the effect that the Committee may have full authority in compliance with the original resolution submitted by the Committee to the Council.

The Committee's interpretation that B-21 did not include the vouchering of bills covering the expenditures of the appropriations for its work, has been confirmed by the minutes of the Council of a

few years ago, when the details of such expenditures were placed in the Secretary's hands as business manager. The rules governing office procedure have, however, been changed to define more clearly this interpretation, resulting in some simplification of the work of the accounting department.

Last spring a number of members of the Society requested a meeting or conference on the subject of Smoke Abatement. This petition and the action of the Committee were referred to the Council on May 28, 1909. This request was for a National Conference with the elimination of the engineering features as far as possible. After due consideration the Committee declined to take favorable action.

Subsequent to the above, the Committee received a second petition asking for a National Conference, but along strictly engineering lines. In the absence of precedent relative to such a Conference, the Committee referred the question to the Council. The Committee has not received, but would gladly receive and carefully consider, a paper on the subject of Smoke Abatement, if presented along strictly engineering lines.

We believe the best interests of the Society make necessary a close working arrangement between the Research and Meetings Committees.

A plan was inaugurated early in the year which it is thought will bring before the Society more new material than has been heretofore available. This is accomplished by correspondence with those interested in original research.

The usual number of meetings were held by the Society during the past year, all of which are now on record. The Committee begs to express its appreciation for the assistance and coöperation during the year of the officers and the several departments of the Society.

WILLIS E. HALL, *Chairman*
WILLIAM H. BRYAN
L. R. POMEROY
CHARLES E. LUCKE
H. DEB. PARSONS
Meetings Committee

REPORT OF THE MEMBERSHIP COMMITTEE

During the current year the Membership Committee has held seven meetings, at which a total of 361 applications for membership have been considered with the following results:

Applications void and withdrawn	11
Applications deferred	11
Recommended for membership	339

There were two ballots during the year on which the applicants recommended by the Committee were voted for. These were at the

Washington meeting	148
New York meeting	187
Total	335

In addition to the most careful consideration which the Secretary and the Membership Committee can give to the applications for membership, the coöperation of the whole voting membership is needed in order to maintain the high standing of the Society. In several instances during the year action by certain members in giving information to the Committee has caused reconsideration of applications, with the result that they have been indefinitely deferred.

A member should not agree to act as proposer or seconder for an applicant unless he actually knows from his own personal observation enough of the latter and his work to be able to answer favorably all the questions on the reference blank regarding him.

The Committee has endeavored to maintain under the By-Laws the standard of qualifications of applicants for whom they have recommended to be voted.

The work of the Committee has been greatly facilitated and expedited by the complete and admirable way in which the cases have been arranged by the Secretary and his staff for presentation to them.

Respectfully submitted,

Henry D. Hibbard, *Chairman*
Charles R. Richards
Francis H. Stillman
George T. Foran
Hosea Webster

Membership Committee

REPORT OF THE PUBLICATION COMMITTEE

The Publication Committee submits herewith the annual report of its work and of the activities under its control for the past year.

The Committee has held frequent meetings and has earnestly endeavored not only to maintain the high standard for the publications of the Society which has previously been set, but also wherever pos-

sible to raise the standard to a new level. In its work upon Volume Thirty of the Transactions which contains the record of the Spring and Winter meetings of 1908, the Committee has given careful study to the available papers with a view of selecting for that volume only those of greatest value for permanent record. After due consideration several papers have been omitted and others have been edited or revised with the approval of the authors. Discussions also have been edited and in some cases considerably condensed in order to separate material of permanent value from that which had but a temporary or passing interest.

In compliance with the Resolutions passed by the Council in April 1909, the Publication Committee has undertaken the general supervision of The Journal in addition to its other duties, and has adopted the following general plan for the conduct of this work:

As a general policy, The Journal should be regarded as the newspaper of the Society and reports of committees, reports of meetings, professional papers of the Society as a whole or of sections, book reviews, Society items, etc., should be published as requested by committees in their official capacity when approved by this Committee, without charging to the committees or activities concerned any expense for publication. The Journal has its own expense account and the appropriation for The Journal should be sufficient to cover editing and publication of this material.

No papers, whether for the meetings of the Society as a whole, or for sections, technical, student or geographical, are to be published except as formally authorized by the Meetings Committee.

Material from standing committees offered officially will, in general, be published in the form which these committees desire.

Reports of meetings of the Society and of sections, except when containing strictly professional papers and discussions will, in general, be published in condensed form.

All matter presented at meetings other than the professional papers provided by the Meetings Committee, including all discussions, will be edited under the direction of the Publication Committee. As a general policy, discussion will be condensed, commercial matter removed, with a view to presenting only engineering data, opinions based on experience, historical notes and similar material of value for permanent record in Transactions.

The advertising section of The Journal which began with the number of September 1908, has proven successful. The income from this source has increased steadily until at the present time there is a

gross annual income from it of $21,000; and through the action of the Council this increased income may be applied to the improving of the quality of, and to the development of The Journal. Plans for such development are under consideration, and it is the purpose of the Committee to make improvements as rapidly as conditions may warrant.

But the most effective work upon the Journal and that which will be of greatest benefit to our membership at large is the careful preparation for publication of the professional material presented at the regular meetings of the Society, and at the meetings of the different sections. In this great fund of material there is always some that is unimportant and irrelevant, and much more that could be made of greater value by skilful editing or by condensation. During the past year the Committee has done much in this direction that has resulted in the improved quality of our paper, and also in a considerable economy of money, and the papers now appearing in The Journal are suitable, with little or no alteration, for publication in the Transactions.

In addition to the volume of the Transactions and The Journal the Committee has issued the annual Year Book of the Society and the Pocket List of Members.

Respectfully submitted,

A. L. Williston, *Chairman*
D. S. Jacobus
H. F. J. Porter
H. W. Spangler
G. I. Rockwood

Publication Committee

REPORT OF THE RESEARCH COMMITTEE

The Research Committee was formally notified of their appointment under date of April 7, 1909, and at the suggestion of the President, the members were requested to meet during the Spring meeting of the Society at Washington. Notice was given a short time in advance of the meeting, and only Prof. R. C. Carpenter and Mr. R. H. Rice were present. These members, however, together with the President of the Society, Jesse M. Smith, and Charles W. Hunt, Past-President, and originator of the suggestion that a Research Committee be appointed, engaged in an informal conference.

A second meeting was called for Wednesday, June 23, 1909, to be held in New York. There were in attendance the President, R. H.

Rice, James Christie, W. F. M. Goss, and the Secretary, Calvin W. Rice. Dr. Goss was chosen Chairman. The Secretary of the Society was recognized as the secretary of the Committee. The minutes of the informal meeting which was held in May were read for the information of the members. After a considerable discussion as to the scope of the work of the Committee, it was agreed that the Committee should have information concerning the laboratories of the various colleges, and other public institutions in America, in which work of engineering research is proceeding, and to this end the Secretary was directed to develop a process which would result in the establishment of such a record in the office of the Society.

It was agreed that the Committee should consider the question of safety valve efficiency. Arrangements were made for gathering in existing information upon this general subject, and steps were taken which will, it is believed, result in a satisfactory outline from which actual work may proceed. Several other subjects for research, referred to the Committee by the Council, were laid on the table for future consideration.

Respectfully submitted

W. F. M. Goss, *Chairman*
James Christie
R. C. Carpenter
Richard H. Rice
Charles B. Dudley

Research Committee

OTHER SOCIETIES

INTERNATIONAL CONGRESS OF MINING, METALLURGY, APPLIED MECHANICS AND PRACTICAL GEOLOGY

An inviation has been extended to the members of The American Society of Mechanical Engineers to attend the International Congress of Mining, Metallurgy, Applied Mechanics and Practical Geology, to be convened at Düsseldorf, June 20-23, 1910, in accordance with the request of the Rhenish-Westphalian Mining Industry made to the Congress of 1905. The 1910 Congress will be divided into four sections, (1) mining, (2) metallurgy, (3) applied mechanics, (4) practical geology. There will be both general and sectional meetings, visits to scientific institutions, industrial undertakings, etc., and excursions to districts of geological interest.

The provisional program includes papers on the Mechanical Preparation of Coal and Ore, the Recovery of By-Products, Briquetting and the Utilization of Low-Grade Fuels; the Production of Pig and Malleable Iron; the History of Machine Construction for Mining and Metallurgical Purposes; Steam Raising; Central Electric Power Stations, Fans and Air-Compressors; Blowing Engine for Blast-Furnaces and Steel Works; Methods of Driving Rolling Mills; Rolling Mills and Accessories; Conveyors for Mining and Smelting Works; and the Utilization of Natural Sources of Water Power.

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the regular meeting of the American Society of Civil Engineers on November 3 at the clubhouse, 220 West 57th Street, New York, two papers were presented for discussion as follows: The Reinforced Concrete Wharf of the United Fruit Company at Bocas del Toro, Panama by T. Howard Barnes; and River Protection Work on the, Kansas City Southern Railway near Braden, Okla., by J. A. Lahmer.

On November 17, the papers discussed were: The Outlet Control of Little Bear Valley Reservoir, by F. E. Trask; and Water Supply for the Lock Canal at Panama, by Julio F. Sorzano, Mem. Am. Soc. M.E.

AMERICAN ASSOCIATION OF REFRIGERATION

At the final meeting of the American Committee of the First International Congress of Refrigerating Industries, held in the Engineering Societies Building, 29 West 39th Street, New York, on May 20, 1909, a permanent national association, styled the American Association of Refrigeration, was formally organized. Since the International Congress held at Paris last year national associations have been formed in Germany, Austria, France, Russia, The Netherlands and other countries. The purpose of the American organization is the facilitation of international intercourse on subjects pertaining to refrigeration and the securing of adequate American representation in international congresses, as well as the study and investigation of problems in refrigeration important to the industry in this country.

It is proposed to hold the Second International Congress of Refrigeration in Vienna, in September 1910, the reports of which will be published in English. Among the questions to be considered are various phases of industrial refrigeration, the application of refrigeration in the food and other industries, and transportation, low temperatures in physical, chemical and biological work, liquified gases, and the hygiene of refrigeration. A tentative program has been issued and can be obtained from the secretary of the American Association of Refrigeration.

It is possible that the Third International Congress of Refrigeration may be held in the United States.

WESTERN SOCIETY OF ENGINEERS

The Western Society of Engineers is now taking steps toward the organization of a Bridge and Structural Section, which, it is hoped, will be in operation in December.

The meetings of the Electrical Section are held jointly with those of the American Institute of Electrical Engineers, Chicago branch. At the first meeting, October 22, W. L. Abbott, Mem.Am.Soc.M.E., presented a paper on Central Station Economies. At the meeting of November 16, Dr. C. P. Steinmetz, Mem.Am.Soc.M.E., will address the meeting.

Among the papers yet to be presented during the winter are: The Panama Railroad and its Relation to the Panama Canal, by Ralph Budd; Progress of the Coal Mine Investigations by the U. S. Geological Survey, by G. S. Rice; River and Harbor Improvements at Chicago

and the Calumet, by Thomas H. Rees; Compressed Air in Contract Work, by M. W. Priseler; Reinforced Concrete Trestles, by C. H. Cartlidge; The Kilbourne Plant of the Southern Wisconsin Power Company, by D. W. Mead, Mem.Am.Soc.M.E.

CHICAGO ASSOCIATION OF COMMERCE

An engineering committee on electrification of railway terminals, appointed by the Chicago Association of Commerce, is composed of the following members: John M. Ewen, *Chairman*, Mem.Am.Soc.M.E.; W. L. Abbott, Mem.Am.Soc.M.E.; B. J. Arnold; Paul P. Bird, Mem.Am.Soc.M.E.: Prof. W.F.M. Goss, Mem.Am.Soc.M.E., and Prof. C. E. Merriam.

PERSONALS OF THE MEMBERSHIP, AM. SOC. M. E.

Edwin E. Arnold, formerly associated with Farrar & Trefts, Buffalo, N. Y., has become identified with the Metal Products Co., Detroit, Mich.

Henry L. Barton has become associated with the Metal Products Co., Detroit, Mich., as vice-president. He was formerly manager of works of the Westinghouse Machine Co., E. Pittsburgh, Pa.

Harry Z. Bixler has become connected with Worth Bros. Company, Coatesville, Pa., as assistant engineer of the blast furnace department.

An article on The Advantages to Electric Companies of Central Station Steam Heating, by Chas. R. Bishop, was published in the October issue of *The Electrical Age*. This paper was read before the New England Branch of the National Electric Light Association, September 9–10, 1909.

W. H. Bradley has been elected president of the American Gas Institute.

Geo. L. Crook, formerly manager of the gas engine department of the Atlas Engine Works, Indianapolis, Ind., has assumed the position of factory manager of Plant No. 3 of the E-M-F Company, Detroit, Mich.

Alfred E. Forstall presented a paper on Sliding-Scale Regulation of Prices and Dividends at the October 20–21 convention of the American Gas Institute.

David Gaehr contributed a paper on Notes on Coal and Ash Handling Equipment at the November 19–20 meeting of the Ohio Society of Mechanical, Electrical and Steam Engineers.

Walter S. Hanson is president of the El Reno Alfalfa Milling Co., El Reno, Okla., a new company organized to build a mill and engage in the manufacture of alfalfa mixed feeds.

E. A. Hitchcock presented a paper on The New Laboratory of the Department of Mechanical Engineering at the Ohio State University, at the November 19–20 meeting of the Ohio Society of Mechanical, Electrical and Steam Engineers.

Edward C. Jones contributed a paper on The Development of Oil Gas in California at the October 20–21 convention of the American Gas Institute.

C. J. Kryzanowsky has become associated with the Reliance Motor Truck Co., Owosso, Mich., as chief engineer. He was until recently manager of the gas engine and producer department of the Olds Gas Power Co., Lansing, Mich.

H. G. Miller has accepted a position as mechanical engineer of the Rubber Regenerating Co., Mishawaka, Ind. Mr. Miller was formerly associated with the S. P. Pond Company, Keokuk, Ia., the Clarinda Poultry, Butter and Egg Co., Clarinda, Ia., and the Iowa Cold Storage Co., Clinton, Ia.

William Newell has prepared a pamphlet on The Prevention of Industrial Accidents, in collaboration with Frank E. Law.

H. F. J. Porter has given the first of his lectures in the graduate school of business administration of Harvard University. He is also a contributor in the correspondence course of instruction in the Hamilton Institute of Business recently established in this city by members of the Faculties of the New York University, the University of Wisconsin, the University of Philadelphia, etc.

Edwin C. Sornborger has become identified with the Allis-Chalmers Co. of Milwaukee, Wis., in the capacity of sales engineer in its pumping engine and hydraulic turbine department. Lieutenant Sornborger was formerly traveling engineer of the Snow Steam Pump Works, Buffalo, N. Y.

In the October issue of the Proceedings of the American Society of Civil Engineers is an article on Water Supply for the Lock Canal at Panama by Julio F. Sorzano. This paper was presented at the November 17 meeting of that Society.

Theodore Stebbins, formerly associated with the Texas Traction Company, and American Railway and Lighting Co., Dallas, Tex., has become a member of the firm of Herrick & Stebbins, with offices in New York.

C. P. Steinmetz gave a lecture on November 16, before a joint meeting of the Chicago Section of the American Institute of Electrical Engineers and the Electrical Section of the Western Society of Engineers, the subject being, The Conservation of Energy.

J. Stewart Thomson, formerly vice-president and treasurer of the New York Safety Steam Power Co., has associated himself with the Harrison Engineering Co., to develop the Harrison air-tube system of heating and ventilating, with offices in New York.

T. Kennard Thomson gave an informal library talk, illustrated with lantern slides, on Pneumatic Foundations. before the Brooklyn Engineers' Club on November 18.

TESTING SUCTION GAS PRODUCERS WITH A KOERTING EJECTOR

By C. M. Garland, Urbana, Ill.
Member of the Society

A. P. Kratz,[1] Urbana, Ill.
Non-Member

The method of testing the suction gas producer herein described, and the forms for computation given in the Appendix to the paper, have been used by the writers to advantage in their gas-producer tests in the mechanical engineering laboratory of the University of Illinois. The method of testing has reduced the labor of running such tests to a minimum, and the forms for computation have greatly reduced the labor and tedium of the calculations.

2 The tests were made on an Otto suction gas producer rated at 60 h.p. and 8000 cu. ft. of gas per hour. The plant as originally installed consisted of the producer *A* (Fig. 1), the wet scrubber *B*, the gas receiver *C*, and a 22-h.p. engine. In order to facilitate the testing of the plant the connection to the 22-h.p. engine was blanked and a Schutte-Koerting steam ejector of 12,000 cu. ft. hourly capacity was placed in the gas main at *F*. This ejector was used to draw the gases from the producer and deliver them to the wet scrubber *G*, where the steam used by the ejector was condensed.

3 The condensed steam and condensing water passed out at the overflow, *M*, while the gases passed out through the separator *N* and into the dryer *H*, constructed from a gas bell, or holder, and filled with straw, and used to separate the suspended moisture from the gases before they entered the meters *I* and *J*. The meters were of 8000 and 3500 cu. ft. hourly capacity respectively, and were connected in parallel for capacities greater than 8000 cu. ft. per hour, the larger meter alone being used for lower capacities. From the meters the

[1]Assistant, Mechanical Engineering Laboratory, Univ. of Ill.

All papers are subject to revision.

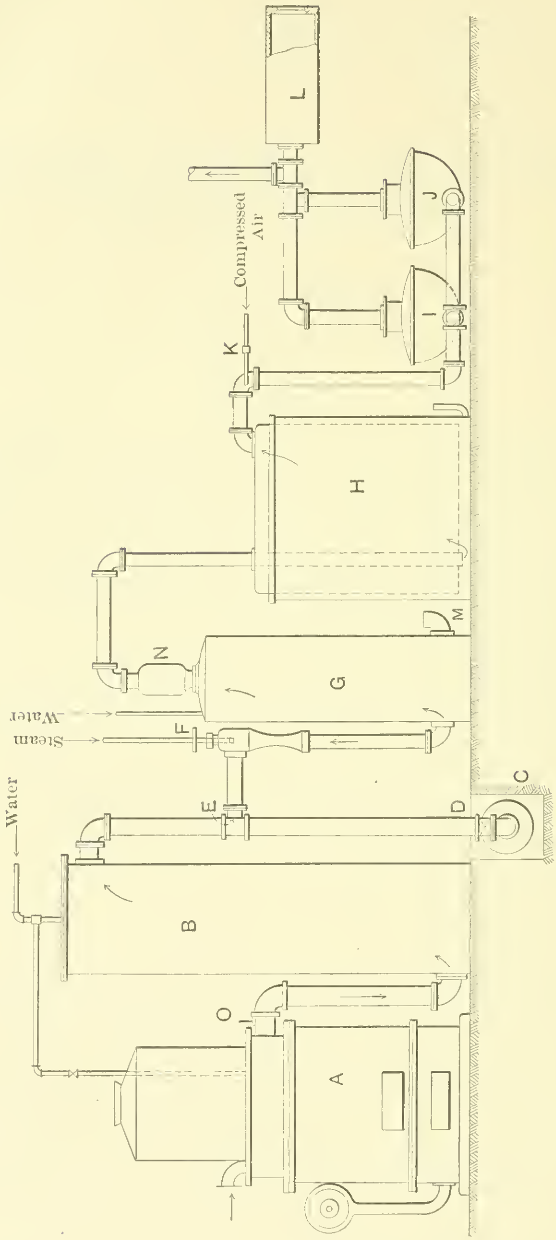

FIG. 1 GENERAL ARRANGEMENT OF SUCTION GAS PRODUCER PLANT TESTED WITH KOERTING EJECTOR

gases were discharged into the atmosphere above the roof of the laboratory.

4 A gage box L was adapted to receive thin plates with orifices, and was used in calibrating the meters, by means of air. The meters having been blanked from the gas main, compressed air was admitted at K, and expanding passed through the meter to be calibrated and out at the orifice in L. The data for the orifice was taken from the paper by R. J. Durley, in Vol. 27, 1906, of the Transactions. After the calibration, the inlet to the box was blanked.

5 The producer is of the contained vaporizer type, with grate and without charging bell, the specifications stating that it is only to be used twelve hours at a time. During some of the earlier tests the cast-iron vaporizer was cracked. A steam jet was then used to supply the moisture, and the vaporizer was blanked off. The weight of steam was measured by passing the jet through a calibrated orifice in a thin plate.

TABLE 1 TEMPERATURES IN FUEL BED

Time	Zone No.	Temp. 3 in. from Near Wall F°	Temp. at Center, F°	Temp. 3 in. from Far Wall F°
10:05–10:10 a.m.	1	2100	2037	2025
10:25–10:30	2	2350	2225	2275
10:43–10:55	3		2200	2400

6 The test was started with the producer full and with a clean fuel bed. The coal fired during the test was weighed and at the end of the test the fire was cleaned, the fuel bed being brought to as near the starting condition as possible, and the producer filled. In order that the error in determining the weight of coal fired in this manner might be known, the producer when cold was filled a number of times, and the weight of coal required was noted. The average of these weights was taken to be the true weight of coal required to fill the producer, the probable error in filling with a given weight of coal being estimated from these results. In running it was endeavored to make the tests of such duration as to bring the probable error of filling down to about two or three per cent.

7 The temperature of the gas leaving the producer was taken at O by means of a platinum-rhodium thermo-couple and a Siemens & Halske milivoltmeter, calibrated to read direct in degrees centigrade.

The temperatures in the fuel bed were taken with Hoskins thermocouples and galvanometer, the latter reading in degrees fahr. Other temperatures were taken with mercury thermometers.

8 The temperatures in the fuel bed were taken in three horizontal zones 10 in., 18 in., and 24 in., respectively, above the grate. In each zone readings were taken 3 in. from the lining on each side, and in the center of the fuel bed. The results are given in Table 1.

9 By means of the sampling tube illustrated in Fig. 2, samples of gas were taken continuously for test by a Junkers calorimeter and for

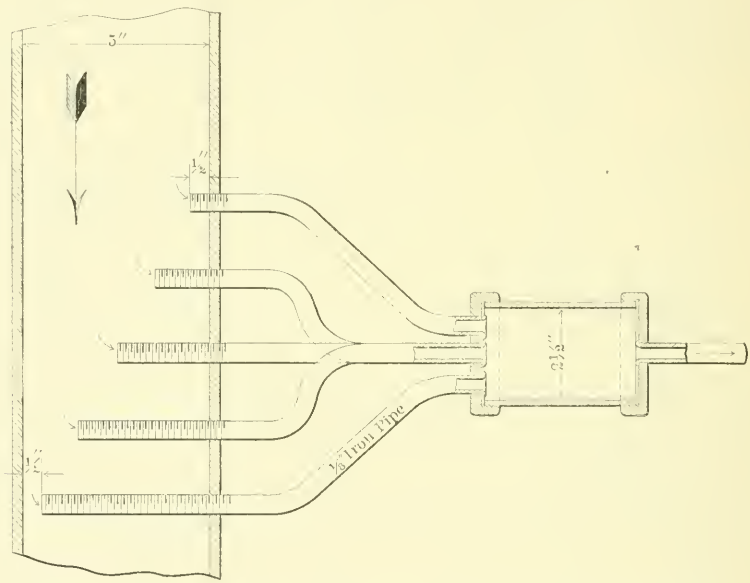

Fig. 2 Sampling Tube for Taking Samples of Gas Continuously

analysis, by Hempel apparatus. The results of the analyses are given in Table 2.

10 As already stated, the weight of steam fed to the producer was determined by the use of a calibrated orifice. By means of a small laboratory aspirator, a sample of the gas leaving the producer was drawn successively through a calcium chloride tube and a small gas meter, the weight of moisture being determined by the calcium chloride tube and the volume by the meter. The per cent of moisture determined by this method was used merely as a check, the percent-

age used in the computations being obtained by calculating the weight of water decomposed from the analysis of the gases and the analysis of the fuel. The difference between this quantity and the total weight of moisture carried into the producer, gives the weight of the moisture in the gas leaving the producer.

11 The volume of gas generated by the producer, and measured by the meters, was also checked by computing the volume of the gas generated from the analyses of gas and coal. In the anthracite producer, where the loss of carbon in soot and tar is small, probably not over 1 per cent, this offers an excellent means of checking the gas volume, and also of computing the weight of air used. The gas analysis, where continuous samples are taken by the form of sampling tube illustrated, should be accurate within 1 per cent. The greatest error is likely to be made in the sampling of the coal. With a fine coal,

TABLE 2 GAS ANAYLSIS BY VOLUME

No.	Time	Per Cent CO_2	Per Cent O_2	Per Cent CO	Per Cent CH_4	Per Cent H_2	Per Cent N_2	B.t.u.
1	6:23– 9:05 a.m.	5.7	0.5	22.9	2.1	12.2	56.6	134
2	9:10–10:37	4.1	0.2	27.9	1.6	11.1	55.1	142
3	10:39–12:25 p.m.	3.3	0.1	28.4	1.5	9.5	57.2	137
4	12:30– 2:52	4.3	0.2	26.9	1.8	10.6	56.2	139
5	3:00– 4:35	3.6	0.1	28.6	1.8	9.0	56.9	139
6	4:40– 6:05	4.1	0.3	27.4	1.8	10.0	56.4	138
Average		4.20	0.23	27.01	1.77	10.40	56.40	138.1

such as pea or buckwheat, and a sample representing from 10 to 20 per cent of the total weight of coal fired, the error in sampling should not exceed 2 per cent. The maximum error in determining the gas volume and the weight of air used should not exceed 5 per cent, if the error in filling the producer is 2 per cent. The probable error is therefore much less. In most of the tests, the volume of gas computed from analysis has checked within 5 per cent the volume determined by the meters. The meters are known to be accurate well within 2 per cent.

12 In the testing of large producers of the bituminous type, it is often difficult to measure the gas volume by any mechanical means. In such cases, if the carbon lost in the soot and tar is estimated from a sample of the soot and tar, and this amount deducted from the total weight of carbon in the coal, the volume may then be computed from

Fig. 3 Graphical Log of Test of Suction Gas Producer

the analyses of the gas and coal, and may be relied upon within 5 per cent, provided the sampling is accurate.

13 In order to facilitate computations, we have prepared three separate forms, or rather two forms and a guide sheet. Form 1 is used only for the presentation of the results of the tests. Form 2 contains all items used in the computations, while Form 3 is the guide sheet containing all of the formulae and their derivation. The items of Form 3 are arranged in the order of computation. In following out this method, the average corrected quantities are taken from the original data sheets and placed on Form 2. The computations are then made by following Form 3. After Form 2 is completed, the results are transferred to Form 1.

14 Referring to Form 1, Item 46, it will be noted that the total ash and refuse is much less than the weight of ash alone that would be obtained by computing from the analysis. This is due to the difficulty in cleaning the ash out of the fuel bed, and partly to the loss of ash in the form of dust, which is carried over into the scrubber. In this particular coal, which had very little tendency to clinker, the ash was soft and fine so that it packed in and filled the interstices between the live coals. A small amount of clinker was formed on the sides.

15 This tendency of the ash to pack in the fuel bed, while it prevents the accurate determination of the actual weight of ash, does not, it is believed, materially affect the determination of the weight of coal as fired, for the reason just given; that is, while the fuel bed may contain as much carbon at the start as at the close, the bed is much more compact due to the ash. The weight of ash and refuse is valuable principally for the determination of the unburned carbon lost through the grate.

16 Item 66, dry coal per sq. ft. of grate area per hour, is high; while the producer was operating only at about 4800 cu. ft. per hour capacity, this was considerably above its actual capacity. If the fuel had contained a fusible ash the results as shown on Form 1 and the graphical log Fig. 3 would have been practically impossible.

17 The heat balance, Form 1, shows the unaccounted-for loss to be 4.4 per cent. This includes radiation and conduction, which for this test probably amounts to between 2 and 3 per cent. By referring to Form 2, Item 126, it will be seen that the volume of standard gas, computed from the analysis of the gas and the analysis of the coal, checks within about 2.3 per cent of the volume of standard gas as given by the meters, Item 125.

18 The graphical log sheet Fig. 3 illustrates the uniformity of conditions that were maintained throughout the test.

19 Permission for running the producer tests was obtained through Prof. L. P. Breckenridge, the results being presented through the courtesy of Dean W. F. M. Goss, of the University of Illinois.

APPENDIX

FORM 1 RESULTS OF GAS PRODUCER TRIALS

1	Test number	25
2	Made by . . . C. M. Garland and A. P. Kratz	
3	At . . . The University of Illinois	
4	Kind of producer . . . Otto	
5	To determine . . . Efficiency	
6	Principal conditions governing trial . . . Uniform load	
7	Kind of fuel . . . Scranton-Anthracite	
8	Kind of grate . . . Plain	
9	Method of starting and stopping test . . . Alternate	
10	Type of producer . . . Suction	
11	Form of blower-ejector . . . Schutte & Koerting	
12	Date of trial	5–29–1909
13	Duration of trial	12 hr.

DIMENSIONS AND PROPORTIONS

14	Dimensions of grate, ft	1.25 by 1.33
15	Grate area, sq. ft	1.666
16	Mean diameter of fuel bed, ft	1.545
17	Depth of fuel bed, ft	2.21
18	Area of fuel bed, sq. ft	1.877
19	Height of discharge pipe above grate, ft	2.875
20	Approximate width of air spaces in grate, inches	0.5
21	Area of air space, sq. ft	0.722
22	Proportion of air space to whole grate area, per cent	43.3
23	Area of discharge pipe, sq. ft	0.165
24	Water heating surface in vaporizer, sq. ft	
25	Outside diameter of shell, ft	2.833
26	Length of shell from base to top of magazine, ft	7.125
27	Ratio of water heating surface to grate area, — to 1	
28	Ratio of minimum draft area to grate area, 1 to	48.8

AVERAGE PRESSURES

29	Draft in ashpit, inches, water	0.61
30	Suction at producer outlet, inches, water	2.04
31	Pressure at meters, inches, water	3.76
32	Corrected barometer reading	29.15
32.1	Steam pressure, lb. per sq. in. gage	90.5

AVERAGE TEMPERATURES

33	Of fire room, deg. fahr	82.2
34	Of steam leaving vaporizer, deg. fahr	212
35	Of feed water entering vaporizer, deg. fahr	
36	Of overflow from vaporizer, deg. fahr	212
37	Of water entering scrubber, deg. fahr	57.8
38	Of water leaving scrubber, deg. fahr	103.6
39	Of gases leaving producer, deg. fahr	1108
40	Of gases leaving scrubber, deg. fahr	84.3
41	Of gases entering meter, deg. fahr	68.0

FUEL

42	Size and condition .... Pea–Clean	
43	Weight of coal as fired, lb	798.5
44	Percentage of moisture in coal	2.75
45	Total weight of dry coal fired, lb	776.5
46	Total ash and refuse, lb	85.0
47	Quality of ash and refuse	
48	Total combustible consumed, lb	614
49	Percentage of ash and refuse in dry coal	10.9

PROXIMATE ANALYSIS OF COAL

50	Fixed carbon	78.45
51	Volatile matter	5.99
52	Moisture	2.75
53	Ash	12.81
54	Sulphur, separately determined	1.10

ULTIMATE ANALYSIS OF DRY COAL

55	Carbon, C	79.84
56	Hydrogen, H_2	2.67
57	Oxygen, O_2	2.37
58	Nitrogen, N_2	0.82
59	Sulphur, S	1.13
60	Ash	13.17
61	Moisture in sample of coal as received	2.75

ANALYSIS OF DRY COAL AND REFUSE

62	Carbon, per cent	38.80
63	Earthy matter, per cent	61.20
	a SiO	
	b Al_2O_3	
	b Fe_2O_3	
	c MgO	
	d CaO	

FUEL PER HOUR

64	Dry coal fired per hr. lb	64.7
65	Combustible consumed per hour, lb	51.2
66	Dry coal per sq. ft. of grate area per hr. lb	38.8
67	Combustible per sq. ft. of grate area per hr. lb	30.7
68	Dry coal per sq. ft. of fuel bed per hr. lb	34.5
69	Combustible per sq. ft. of fuel bed per hr. lb	27.3
70	Rate of descent of dry coal through fuel bed, lb. per ft. per sq. ft. per hr	15.6
71	Rate of descent of combustible through fuel bed, lb. per ft. per sq. ft. per hr	12.4

CALORIFIC VALUE OF FUEL

72	Calorific value by oxygen calorimeter per lb. dry coal, B.t.u.	13040
73	Calorific value by oxygen calorimeter per lb. of combustible B.t.u	15700
74	Calorific value by analysis per lb. dry coal, B.t.u	13125
75	Calorific value by analysis per lb. of combustible, B.t.u	15800

WATER

76	Total[1] weight of water fed to vaporizer, lb	267.8
77	Total weight of overflow from vaporizer, lb	0.0
78	Water[1] actually evaporated in vaporizer, lb	267.8
79	Total weight of water fed to producer, lb	341.5
	a From vaporizer[1]	267.8
	b In air	51.7
	c In coal	22.0
80	Total weight of water decomposed	218.2
81	Total weight of water in gas leaving producer, lb	123.3
82	Ratio of water decomposed to water supplied	0.639
83	Weight of water decomposed per lb. gas generated, lb	0.0558
84	Weight of water decomposed per lb. of dry coal fired, lb	0.281
85	Weight of water decomposed per lb. of combustible consumed, lb	0.355
86	Weight of water decomposed per lb. of air supplied, lb	0.0702
87	Weight of water supplied per lb. of dry coal fired, lb	0.440
88	Weight of water supplied per lb. of combustible consumed, lb.	0.556
89	Weight of water supplied per lb. of dry air used, lb	0.1097
90	Total weight of scrubber water, lb.	22200

WATER PER HOUR

91	Water evaporated per hr. in vaporizer, lb	
92	Water evaporated per hr. per sq. ft. of water heating surface in vaporizer, lb	
93	Weight of water decomposed per hr., lb.	18.2

[1] Steam fed to vaporizer

94	Total weight of water fed to producer per hr., lb.	28.5
95	Weight of scrubber water used per hr., lb.	1850.0

QUANTITY OF AIR

96	Per cent of moisture in air, per cent of dry air	1.66
97	Total weight of dry air, lb.	3112.
98	Total weight of dry air per hr. lb.	259.2
99	Weight of dry air used per lb. of dry coal fired, lb.	4.01
100	Weight of dry air used per lb. of combustible consumed, lb.	5.07
101	Weight of dry air used per lb. of dry gas generated, lb.	0.796

GAS

102	Per cent moisture in gas leaving producer, per cent of dry gas	3.15
103	Per cent of soot and tar in gas leaving producer	
104	Calorific value of standard gas from analysis (high value) B.t.u. per cu. ft.	138.1
105	Calorific value of standard gas from calorimeter, (high value) B.t.u. per cu. ft.	137.3
106	Specific weight of standard gas, lb. per cu. ft.	0.0680
107	Specific heat of dry gas leaving producer	0.3281
108	Carbon ratio C/H	14.07
109	Total volume standard gas, cu. ft.	57500.
110	Volume of standard gas per hr. cu. ft.	4795.
111	Volume of standard gas per lb. of dry coal	74.1
112	Volume of standard gas per lb. of combustible	93.7
113	Total weight of standard gas, lb.	3912
114	Weight of standard gas per hr., lb.	326
115	Weight of standard gas per lb. of dry coal fired, lb.	5.03
116	Weight of standard gas per lb. of combustible consumed, lb.	6.37

GAS ANALYSIS BY VOLUME

117	Carbon dioxide, CO_2	4.20
118	Carbon monoxide, CO	27.01
119	Oxygen, O_2	0.23
120	Hydrogen, H_2	10.40
121	Marsh gas, CH_4	1.77
122	Olefiant gas, C_2H_4	
123	Sulphur dioxide, SO_2	
124	Hydrogen sulphide, H_2S	
125	Nitrogen, N_2, by difference	56.40

EFFICIENCY

126	Grate efficiency, per cent	95.3
127	Hot gas efficiency, based on high heating value, per cent	90.9
128	Cold gas efficiency, based on high heating value, per cent	78.3

EFFICIENCY BASED ON COMBUSTIBLE

128*a*	Hot gas efficiency, based on high heating value	95.4
128*b*	Cold gas efficiency, based on high heating value	82.2

COST OF GASIFICATION

129	Cost of fuel per ton delivered in producer room	
130	Cost per 1000 cu. ft. of standard gas, cents	
131	Cu. ft. scrubber water per 1000 cu. ft. gas	6.18

POKING

132	Method of poking	From top, slicing from bottom
133	Frequency of poking	Three times during run

FIRING

134	Method of firing	Hand
135	Average intervals between firing	Twice during run
136	Average amount of fuel charged each time, lb.	250

HEAT BALANCE

Debit	B.t.u.
a Total heat supplied per lb. dry coal	13040
b Total heat supplied by air per lb. dry coal	19
c Total heat supplied by moisture in air per lb. dry coal	
d Total heat supplied by moisture in coal per lb. dry coal	
e Total heat supplied as sensible heat in coal per lb. dry coal	
f Total[1] heat supplied by water in vaporizer per lb. dry coal	385
Total	13444

Credit	B.t.u.	Per Cent
a Heat contained as sensible heat in dry gas	1725	12.8
b Heat contained in moisture	262	2.0
c Heat contained in dry gas (heat of combustion)	10240	76.2
d Heat in unburned carbon	618	4.6
e Heat contained in ash and refuse as sensible heat		
f Heat lost in overflow from vaporizer		
g Heat lost in radiation and conduction	599	4.4
Total	13444	100.0

[1] Supplied in steam.

FORM No. 2 RESULTS OF GAS PRODUCER TRIALS

NO. OF TEST 25. DATE, 5/29/09. TIME OF START 6.15 A.M. TIME OF STOP 6.15 P.M. DURATION OF TRIAL, 12 HRS. KIND OF FUEL SCRANTON-ANTHRACITE

DIMENSIONS AND PROPORTIONS

1	Dimensions of grate, ft.	1.25 by 1.33
2	Grate area, sq. ft.	1.666
3	Mean diameter of fuel bed, ft.	1.545
4	Depth of fuel bed, ft.	2.21
5	Area of fuel bed, sq. ft.	1.877
6	Height of discharge pipe above grate, ft.	2.875
7	Approximate width of air spaces in grate, inches	0.5
8	Area of air space, sq. ft.	0.722
9	Ratio of air space to whole grate area	1 to 2.3
10	Area of discharge pipe, sq. ft.	0.165
11	Water heating surface in vaporizer, sq. ft.	
12	Outside diameter of shell, ft.	2.833
13	Length of shell from base to top of magazine, ft.	7.125
14	Ratio of water heating surface to grate area — to 1	
15	Ratio of minimum draft area to grate area	1 to 48.8

AVERAGE PRESSURES

16	Average barometer reading, inches Hg	29.258
17	Average corrected barometer reading, inches Hg	29.152
18	Draft in ash pit, inches water	0.61
19	Suction at producer outlet, inches water	2.04
20	Absolute pressure at producer outlet, inches Hg	29.00
21	Suction[1] at orifice, inches water	90.5
22	Absolute pressure[1] at orifice, inches Hg	104.8
23	Pressure at meters, inches water	3.76
24	Absolute pressure at meters, inches Hg	29.43
25	Vapor pressure at meters, inches Hg	0.685
26	Dry gas pressure at meters, inches Hg	28.75
27	Suction at meter for dryer, inches water	2.04
28	Absolute pressure at meter for dryer, inches Hg	29.00

AVERAGE TEMPERATURES

29	At barometer, deg. fahr.	78.0
30	Of fire room, deg. fahr.	82.2
31	Of fire room, deg. absolute fahr	542.2
32	Of steam, deg. fahr.	212
33	Of feed water entering vaporizer, deg. fahr	
34	Overflow from vaporizer, deg. fahr	212
35	Rise in vaporizer, deg. fahr	

[1]Steam pressure

36	Of water entering scrubber, deg. fahr	57.8
37	Of water leaving scrubber, deg. fahr	103.6
38	Rise in scrubber, deg. fahr	45.8
39	Of gases leaving producer, deg. fahr	1108
40	Of gases leaving producer, deg. abs. fahr	1568
41	Of gases leaving first scrubber, deg. fahr	84.3
42	Of gases leaving first scrubber, deg. abs. fahr	544.3
43	Drop in temperature of gases in scrubber, deg. fahr	1023.7
44	Of gases entering meters, deg. fahr	68.0
45	Of gases entering meters, deg. abs. fahr	528
46	Of gas at meter at dryer, deg. fahr	80.0
47	Of gas at meter at dryer, deg. abs. fahr	540

FUEL

48	Size and condition ... Pea, Clean	
49	Weight of coal as fired, lb	798.5
50	Percentage of moisture in coal	2.75
51	Total weight of dry coal fired, lb	776.5
52	Total ash and refuse, lb	85.0
53	Quality of ash and refuse	
54	Total weight of combustible, lb	614
55	Percentage of ash and refuse in dry coal, per cent	10.9

PROXIMATE ANALYSIS OF COAL

56	Fixed carbon, per cent	78.45
57	Volatile matter, per cent	5.99
58	Moisture, per cent	2.75
59	Ash, per cent	12.81
60	Sulphur, separately determined, per cent	1.10

ULTIMATE ANALYSIS OF DRY COAL

61	Carbon, C, per cent	79.84
62	Hydrogn, H_2, per cent	2.67
63	Oxygen, O_2, per cent	2.37
64	Nitrogen, N_2, per cent	0.82
65	Sulphur, S, per cent	1.13
66	Ash, per cent	13.17
67	Moisture in sample of coal as received, per cent	2.75

ANALYSIS OF DRY ASH AND REFUSE

68	Carbon, per cent	38.80
69	Earthy matter, per cent	61.20
	a SiO_2	
	b $\begin{cases} Al_2O_3 \\ Fe_2O_3 \end{cases}$	
	c MgO	
	d CaO	

FUEL PER HOUR

70	Dry coal fired per hr., lb.	64.7
71	Combustible consumed per hr., lb.	51.2
72	Dry coal sq. ft. of grate area per hr., lb.	38.8
73	Combustible per sq. ft. of grate area per hr., lb.	30.7
74	Dry coal per sq. ft. of fuel bed per hr., lb.	34.5
75	Combustible per sq. ft. of fuel bed per hr., lb.	27.3
76	Rate of descent of dry coal through fuel bed, lb. per ft. per sq. ft. per hr.	15.6
77	Rate of descent of combustible through fuel bed, lb. per ft. per sq. ft. per hr.	12.4

CALORIFIC VALUE OF FUEL

78	Calorific value by oxygen calorimeter per lb. dry coal, B.t.u.	13040
79	Calorific value by oxygen calorimeter per lb. combustible, B.t.u.	15700
80	Calorific value by analysis, per lb. dry coal, B.t.u.	13125
81	Calorific value by analysis, per lb. combustible, B.t.u.	15800

WATER

82	Total[1] weight fed to vaporizer, lb.		267.8
83	Total weight of overflow, lb.		0.0
84	Water[1] actually evaporated in vaporizer, lb.		267.8
85	Weight of water fed to producer,		
	a From vaporizer[1]	267.8	
	b In air	51.7	
	c In coal	22.0	
	Total		341.5
86	Total weight of water decomposed from analysis, lb.		218.2
87	Total weight of water decomposed as used in calculations, lb.		218.2
88	Total weight of moisture in gas leaving producer, lb.		123.3
89	Ratio of water decomposed to water supplied		0.639
90	Weight of water decomposed per lb. of gas generated, lb.		0.0558
91	Weight of water decomposed per lb. of dry coal fired, lb.		0.281
92	Weight of water decomposed per lb. of combustible consumed, lb.		0.355
93	Weight of water decomposed per lb. of air supplied		0.0702
94	Weight of water supplied per lb. of dry coal fired, lb.		0.440
95	Weight of water supplied per lb. of combustible consumed, lb.		0.556
96	Weight of water supplied per lb. of air used, lb.		0.1097
97	Total weight of scrubber water, lb.		22200.
98	Total weight of water absorbed by dryer		15.

[1] Steam fed to vaporizer.

WATER PER HOUR

99	Water evaporated per hr. in vaporizer, lb	
100	Water evaporated per hr. per sq. ft. of water heating surface in vaporizer, lb	
101	Weight of water decomposed per hr., lb	18.2
102	Total weight of water fed to producer per hr., lb	28.5
103	Weight of scrubber water used per hr. lb	1850

QUANTITY OF AIR

104	Relative humidity of air, per cent	73.
105	Per cent of moisture contained in air, per cent by weight of dry air	1.66
106	Total weight of dry air by analysis, lb	3112
107	Total weight of dry air by orifice, lb	
108	Total weight of dry air as used in calculations, lb	3112
109	Weight of dry air per hr. from total used in calculations	259.2
110	Weight of dry air used per lb. of dry coal fired, lb	4.01
111	Weight of dry air used per lb. of combustible consumed, lb	5.07
112	Weight of dry air used per lb. of dry gas generated, lb	0.796

GAS

113	Volume of gas passing through meter at dryer, cu. ft	31.06
114	Volume of standard gas passing through meter at dryer, cu. ft.	28.0
115	Total weight of gas passing through dryer meter, lb	1.9
116	Percentage of moisture in gas leaving producer, from dryer, per cent dry gas	1.74
117	Percentage of moisture in gas leaving producer, from water fed to producer, per cent dry gas	3.15
118	Percentage soot and tar in gas leaving producer, per cent	
119	Calorific value per cu. ft. of standard gas from analysis B.t.u. (high value)	138.1
120	Calorific value per cu. ft. of standard gas from calorimeter, B.t.u. (high value)	137.3
121	Specific weight of standard gas, lb. per cu. ft	0.0680
122	Specific heat of dry gas leaving producer	0.3281
123	Carbon ratio C/H	14.07
124	Total volume of gas from meters, cu. ft	60630
125	Total volume of standard gas, from meters, cu. ft	57500.
126	Total volume of standard gas, from analysis, cu. ft	56200
127	Total volume as used in calculations, cu. ft	57500
128	Volume of standard gas per hr. from total used in calculations.	4795
129	Volume of standard gas per lb. of dry coal from total used in calculations, cu. ft	74.1
130	Volume of standard gas per lb. of combustible from total used in calculations, cu. ft	93.7
131	Total weight of standard gas from total used in calculations, lb	3912

132	Weight of standard gas per hr., lb.	326
133	Weight of standard gas per lb. of dry coal, lb.	5.03
134	Weight of standard gas per lb. of combustible, lb.	6.37

GAS ANALYSIS BY VOLUME

135	Carbon dioxide, CO_2	4.20
136	Carbon monoxide, CO	27.01
137	Oxygen, O_2	0.23
138	Hydrogen, H_2	10.40
139	Marsh gas, CH_4	1.77
140	Olefiant gas, C_2H_4	
141	Sulphur dioxide, SO_2	
142	Hydrogen sulphide, H_2S	
143	Nitrogen, N_2 by difference	56.40

GAS ANALYSIS BY WEIGHT

144	Carbon dioxide, CO_2	7.16
145	Carbon monoxide, CO	29.25
146	Oxygen, O_2	0.29
147	Hydrogen, H_2	0.81
148	Marsh gas, CH_4	1.12
149	Olefiant gas, C_2H_4	
150	Sulphur dioxide, SO_2	
151	Hydrogen sulphide, H_2S	
152	Nitrogen, N_2, by difference	61.37

EFFICIENCY

153	Grate efficiency, per cent	95.3
154	Hot gas efficiency, based on high heating value, per cent	90.9
155	Cold gas efficiency, based on high heating value, per cent	78.3

EFFICIENCY BASED ON COMBUSTIBLE

155*a*	Hot gas efficiency, based on high heating value, per cent	95.4
155*b*	Cold gas efficiency, based on high heating value, per cent	82.2

COST OF GASIFICATION

156	Cost of fuel per ton delivered in producer room	
157	Cost per 1000 cu. ft. of standard gas, cents	
158	Cu. ft. scrubber water per 1000 cu. ft. standard gas	6.18

POKING

159	Method of poking	From top, slicing from bottom
160	Frequency of poking	Three times during test

FIRING

161	Method of firing	Hand
162	Average intervals between firings	Twice during run
163	Average amount of fuel charged each time	250

HEAT BALANCE

Debit		B.T.U.
a Total heat supplied per lb. dry coal		13040
b Total heat supplied by air per lb. dry coal		19
c Total heat supplied by moisture in air per lb dry coal		
d Total heat supplied by moisture in coal		
e Total heat supplied as sensible heat in coal		
f Total[3] heat supplied in vaporizer water		385
Total	13444	

Credit	B.T.U.	Per Cent
a Heat contained as sensible heat in dry gas	1725	12.8
b Heat contained in moisture	262	2.0
c Heat contained in dry gas (heat of combustion)	10240	76.2
d Heat in unburned carbon	618	4.6
e Heat contained as sensible heat in ash and refuse		
f Heat lost in overflow from vaporizer		
g Radiation and conduction, by difference	599	4.4
Total	13444	100.0

FORM 3 GUIDE SHEET CONTAINING ALL FORMULAE AND THEIR DERIVATION

The item numbers refer to the items of Form 2, and are arranged in the order of computation.

Item 4. "Depth of fuel bed" is to a certain extent arbitrary. In order that the term may have a fixed and definite meaning we will define it as the distance between the upper edge of the ash zone and that section of the fuel bed from which the gases separate and leave the fuel. The upper edge of the ash zone can ordinarily be readily determined by inspection.

Item 16. This reading is the average of the barometer readings for the test and is not corrected.

Item 17. Item 16 corrected. The following formula may be used:

Let H = corrected barometer reading.

t = temperature, deg. fahr.

h = barometer reading corresponding to temperature t.

Then $H = h\,(1.00254 - 0.000079t)$

Item 17. = Item 16 (1.00254 − 0.000079 × Item 29)

Item 18. = Observed.

Item 19. = Observed.

Item 20. = Item 17 − Item 19 × 0.0735

Item 21. = Observed.

Item 22. = Item 17 − Item 21 × 0.0735

[3] Supplied in steam.

Item 23. = Observed.
Item 24. = Item 17 + Item 23 × 0.0735
Item 25. = Taken from steam tables using temperature in Item 44, 1 lb. per sq. in. = 2.04 in. Hg.
Item 26 = Item 24 − Item 25
Item 27. = Observed.
Item 28. = Item 17 − Item 27 × 0.0735
Items 29 to 48. The observed temperatures should be corrected from the calibration curves before being placed in Form 2. The absolute temperature = the observed temperature + 460 deg.
Item 39. This item is observed in deg. cent. and should be transferred into deg. fahr.

$$\text{Deg. fahr.} = \frac{9}{5}\,\text{deg. cent.} + 32$$

Each observation must be transferred.
Item 50. Taken from Item 67.

$$\textit{Item}\ 51.\quad \text{Item } 49\left(1 - \frac{\text{Item } 50}{100}\right)$$

Item 52. Taken from ash sheet, correction being made for any moisture taken up in the ashpit.
Item 54. In these tests the total weight of combustible consumed will be taken as the total weight of dry coal fired.
The weight of ash is computed from the analysis.
The weight of nitrogen = $\frac{9}{8}$ × the weight of oxygen.
The weight of carbon contained in the ash and refuse equals

$$\text{Item } 51 - \frac{\text{Item } 51 \times \text{Item } 66}{100} - \frac{\text{Item } 51 \times \text{Item } 64}{100} - \frac{\frac{9}{8}\,\text{Item } 51 \times \text{Item } 63}{100}$$
$$- \frac{\text{Item } 52 \times \text{Item } 68}{100}$$

Therefore,

$$\text{Item } 54 = \text{Item } 51\left[1 - \frac{\text{Item } 66 + \text{Item } 64 + \frac{9}{8}\,\text{Item } 63}{100}\right] - \frac{\text{Item } 52 \times \text{Item } 68}{100}$$

$$\textit{Item}\ 55. = \frac{\text{Item } 52 \times 100}{\text{Item } 51}$$

Items 56 to 69. From chemist.
Items 69, 1,2, 3, *and* 4. The ultimate analysis of the ash will be made only in special cases to obtain data on the formation of clinker.

$$\textit{Item}\ 70. = \frac{\text{Item } 51}{\text{hours}}$$

$$\textit{Item}\ 71. = \frac{\text{Item } 54}{\text{hours}}$$

Item 72. $= \dfrac{\text{Item } 70}{\text{Item } 2}$

Item 73. $= \dfrac{\text{Item } 71}{\text{Item } 2}$

Item 74. $= \dfrac{\text{Item } 70.}{\text{Item } 5}$

Item 75. $= \dfrac{\text{Item } 71.}{\text{Item } 5}$

Item 76. "The rate of descent of dry coal through the fuel bed," or "The dry coal per cu. ft. of fuel bed per hour," which is the same, offers a means of comparing the rate of gasification in different producers that seems to be better adapted for the purpose than the expressions taken from boiler pratice, viz: "coal per sq. ft. of grate area," or "coal per sq. ft. of fuel bed," the latter having been used in producer practice.

Item 76. $= \dfrac{\text{Item } 74}{\text{Item } 4}$

Item 77. $= \dfrac{\text{Item } 75}{\text{Item } 4}$

Item 78. Taken from chemist's report.

Item 79. $= \dfrac{\text{Item } 78 \times \text{Item } 51 - \text{Item } 52 \times \text{Item } 68 \times 145.40}{\text{Item } 54}$

Item 80. $= \left\{\text{Item } 61 \times 145.40 + \text{Item } 65 \times 40.00 + [\text{Item } 62 - \frac{1}{8} \text{ of Item } 63] \times 620.00\right\}$

Item 81. $= \dfrac{\text{Item } 80 \times \text{Item } 51 - \text{Item } 52 \times \text{Item } 68 \times 145.40}{\text{Item } 54}$

Item 113. Total volume of gas passing through meter at dryer. Observed

Item 114. Total volume of standard gas passing through meter at dryer. Neglecting the effect of moisture.

Let p_1 = absolute pressure in inches Hg. at dryer meter.
t_1 = absolute temperature, deg. fahr. at dryer meter.
v_1 = total volume of gas passing through meter.
P, V, and T, be the condition of standard gas.
$P = 30$ in. Hg.
$T = 460 + 62 = 522$
$V = ?$

Then

$$\frac{p_1v_1}{t_1} = \frac{PV}{T}$$

$$\text{or } V = \frac{p_1v_1T}{Pt_1} = \frac{p_1v_1 \times 522}{30t_1} = \frac{17.4\ p_1v_1}{t_1}$$

from which the value of Item 114 follows.

Item 114. $= 17.4 \dfrac{\text{Item } 28 \times \text{Item } 113}{\text{Item } 47}$

Item 118. Not considered in these tests.

Item 119. One cubic foot of standard gas, that is, gas at a temperature of 62 deg. fahr. or 522 deg. absolute and a pressure of 30 in. Hg., gives up on combustion, when the products of combustion are brought back to this temperature and the moisture is condensed, the following heat quantities:

H_2 = 328 B.t.u. per cu. ft. of standard gas.
C_2H_4 = 1480 B.t.u. per cu. ft. of standard gas.
CO = 319 B.t.u. per cu. ft. of standard gas.
CH_4 = 1010 B.t.u. per cu. ft. of standard gas.

Item 120. This quantity is the average of all the calorimeter determinations. Each separate determination by the calorimeter must be computed and the heating value obtained. The following formula may be used. The calorimeter readings are taken in centigrade units with the exception of the meter readings and pressure.

Let t_2 = temperature of entering water, deg. cent.
t_1 = temperature leaving water, deg. cent.
r = rise in temperature of water, deg. cent.
W = weight of water used during the intervals = 8 litres for all tests.
G_1 = cu. ft. of gas used from meter.
t_g = temperature of entering gas, deg. cent.
p_g = pressure entering gas inches Hg. absolute, corrected for vapor pressure of water (see Item 25).
H = heating value per cu. ft. of standard gas (62 deg. fahr. or 16.7 deg. cent. and 30 in. Hg.)
t_s = temperature of standard gas = 62 deg. fahr. or 16.7 deg. cent.
p_s = pressure of standard gas = 30 in. Hg.
G_s = cu. ft. of standard gas.

$$\frac{G_1\, p_g}{t_g} = \frac{G_s\, p_s}{t_s}$$

$$G_s = \frac{G_1 \times p_g \times t_s}{t_g \times p_s}$$

Where t_g and t_s are in absolute deg. cent., $t_1 - t_2 = r$
Total heat per cu. ft. standard gas in B.t.u. = H.
Total heat absorbed by water = W $\times r$

$$H = \frac{W \times r \times 3.968}{G_s} = \frac{W \times r \times 3.968}{\dfrac{G_1 \times p_g \times t_s}{t_g \times p_s}}$$

$$= \frac{8 \times r \times 3.968 \times t_g \times 30}{G_1 \times p_g \times (16.7 + 273)} =$$

$$\frac{t_g \times r \times 3.29}{G_1 \times p_g}$$

where 3.968 is the conversion factor.

In this formula it is assumed that the exhaust products are brought back to 62 deg. fahr. This is not strictly true but the error introduced is negligible, when the error in the use of the apparatus is considered. There is another error due to the exhaust products carrying out more or less vapor of water than was brought in by the entering gas and air.

This error will also be small and may either be positive or negative depending on conditions. The entering gas will in most cases come from direct contact with water and will therefore be saturated. The air ordinarily will not be saturated. On combustion, moisture will be formed by the union of the oxygen and hydrogen, there will be a contraction in volume of the gases due to the combustion, and also a contraction or expansion due to a change in temperature after combustion. In whichever direction the change in the weight of moisture in the out-going gas from that brought in by the entering gas may occur, this change may be considered very small; for the contraction on combustion will be comparatively small, and this contraction will partly offset the unsaturated condition of the air used for combustion. Also the change in temperature of the out-going gas from that of the entering gas will be small.

The heating values as given in Items 119 and 120 are the *high values*.

The values obtained from the analysis will be more accurate and will be used in all computations.

Item 121. The specific weights of the following gases at 62 deg. and 30 in. Hg. are

$CO_2 = 0.11610$	$CH_4 = 0.04278$
$CO = 0.07362$	$C_2H_4 = 0.07370$
$O_2 = 0.08418$	$SO_2 = 0.16380$
$H_2 = 0.00530$	$H_2S = 0.08682$

$$N_2 = 0.07400$$

Item 121. = [Item 135 × 0.1161 + Item 136 × 0.07362 + Item 137 × 0.08418 + Item 138 × 0.00530 + Item 139 × 0.04278 + Item 140 × 0.0737 + Item 141 × 0.1638 + Item 142 × 0.08682 + Item 143 × 0.0740] $\frac{1}{100}$

Items 144 to 152. Calculation of the gas analysis by weight from the analysis by volume. Assume that we have one cubic foot of gas at 62 deg. fahr. and 30 in. Hg. of the following composition:

Volumetric Analysis	Specific Weights	Analysis by Weight Per Cent
$CO_4 = a$ per cent	$0.1161 = W_a$	$a = \frac{W_a \times a}{W}$
$CO = b$	$0.07362 = W_b$	$b = \frac{W_b \times b}{W}$
$O_2 = c$	$0.08418 = W_c$	$c = \frac{W_c \times c}{W}$
$H_2 = d$	$0.00530 = W_d$	$d = \frac{W_d \times d}{W}$

Volumeric Analysis	Specific Weights	Analysis by Weight Per Cent
$CH_4 = e$	$0.04278 = W_e$	$e = \frac{W_e \times e}{W}$
$C_2H_4 = f$	$0.07370 = W_f$	$f = \frac{W_f \times f}{W}$
$SO_2 = g$	$0.16380 = W_g$	$g = \frac{W_g \times g}{W}$
$H_2S = h$	$0.08682 = W_h$	$h = \frac{W_h \times h}{W}$
$N_4 = i$	$0.07400 = W_i$	$i = \frac{W_i \times i}{W}$

Where $W = [a \times W_a + b \times W_b + c \times W_c + e \times W_e \ldots + i \times W_z] \frac{1}{100}$ = Item 121.

Item 122. The specific heats of the gases vary according to the pressure and temperature. As the pressure used throughout the experiments is atmospheric we have only to consider the variation with the temperature. The following formulae taken from Zeuner, vol. I, page 147, give the specific heat for constant volume C_v.

[1]CO_2, $mC_v = 6.50 + 0.00774t$ .... (1)
H_2O, $mC_v = 5.78 + 0.00572t$ .... (2)
$O_2\ H_2\ N_2$, CO, $mC_v = 4.76 + 0.00244t$ .... (3)
$mC_p - mC_v = 1.9934$ .... (4)

For the specific heat of marsh gas CH_4, our other constituent, we will use the value $C_p = 0.6$. This is approximate, but as the quantity of CH_4 is small the resultant error is consequently small.

In the above formula, m is the molecular weight of the gas, t the temperature in deg. cent, and C_v the mean specific heat between zero and t deg. cent. C_p is determined from formula (4). From the above formulæ, the analysis by weight as determined below and the temperature of the gases leaving the producer, the specific heat of each constituent in a unit weight of the gas may be determined. The specific heat of the gas will be the sum of the specific heats of the constituents.

Substituting the value of mC_v from formula (4), and the value of m, and changing to deg. fahr. we have from the above formulae:

For CO_2, $C_p = 0.19 + .0000977t$ .... *a*
H_2O, $C_p = 0.426 + .000176t$ .... *b*
H_2, $C_p = 3.355 + .000678t$ c
CO, $C_p = 0.24 + .0000484t$ .... *d*
N_2, $C_p = 0.24 + .0000484t$ .... *e*
CH_4, $C_p = 0.6$ .... *f*
O_2, $C_p = 0.21 + .0000424t$ .... *g*

[1]Mallard and Le Chatellier's Formulae.

Let a, b, c, d, e, and f, represent the mean C_p for the above gases between 32 deg. and t deg. fahr. Then the C_p of the producer gas = the sum of the products of the constituents of the gas by weight $\times$ the specific heat of the constituent.

That is,

$$\text{Item } 122 = [a \times \text{Item } 144 + c \times \text{Item } 147 + d \times \text{Item } 145 + e \times \text{Item } 152 + f \times \text{Item } 148 + g \times \text{Item } 146] \frac{1}{100}$$

Item 123

1	2	3	4
$CO_2 = O_2 + C$	$CO = C + O$	$CH_4 = C + 2H_2$	$C_2H_4 = 2C + 2H_2$
$44 = 32 + 12$	$28 = 12 + 16$	$16 = 12 + 4$	$28 = 24 + 4$

The total weight of carbon appearing in a unit weight of gas from the above = per cent by weight $CO_2 \times \frac{3}{1100}$ + per cent by weight $CO \times \frac{3}{700}$ + per cent by weight $CH_4 \times \frac{3}{400}$ + per cent by weight $C_2H_4 \times \frac{6}{700}$

The total weight of H_2 appearing in a unit weight of gas = per cent by weight $\frac{H_2}{100}$ + per cent by weight $CH_4 \times \frac{1}{400}$ + per cent by weight $C_2H_4 \times \frac{1}{700}$.

or Item 123 = [Item 144 $\times$ 0.273 + Item 145 $\times$ 0.429 + Item 148 $\times$ 0.75 + Item 149 $\times$ 0.858] $\div$ [Item 147 + Item 148 $\times$ 0.25 + Item 149 $\times$ 0.143]

Item 124. Observed.

Item 125. Let G = total volume of gas as measured by the meters.

p = absolute pressure of this gas in inches Hg. as observed.

T = absolute temperature in deg. fahr.

t = observed temperature.

The volume of gas G as measured by the meter is saturated with water vapor at the temperature t.

Let p_1 = pressure of this vapor in inches as obtained from the steam table.

Then as the pressure p is the total pressure of the mixture, the actual or partial pressure of the dry gas is $p - p_1 = p_2$.

Let p_s, G_s, and T_s. be the condition of standard gas. Then

$$\frac{G_s \times p_s}{T_s} = \frac{G \times p_2}{T} \text{ or } G_s = \frac{G \times p_2 \times T_s}{T \times p_s} = \frac{G \times p_2 \times 522}{T \times 30} = \frac{G \times p_2}{T} \times 17.4$$

Therefore Item 125 equals

$$\frac{\text{Item } 124 \times \text{Item } 26 \times 17.4}{\text{Item } 45}$$

Item 126. Calculation of the volume of the gas from the analysis of the gas and the analysis of the coal. Evidently the total weight of the carbon appearing in the gas should be equal to the total weight of carbon in the coal minus the weight that is lost through the grate and the weight lost in soot and tar. This latter is small for the hard-coal producer and will be neglected.

Let P = Per cent carbon by weight in dry coal.
W = total weight of dry coal.
W_1 = total weight of ash and refuse.
P_1 = Per cent by weight of carbon in the ash and refuse.
W_2 = total weight of carbon that should appear in the gas, or the weight of carbon utilized in the producer.

$$W_2 = \frac{PW - P_1W_1}{100}$$

This carbon is contained in the CO_2, CO, CH_4, and C_2H_4.

The proportion by weight of C in CO_2 is 3/11, of C and CO is 3/7, of C in CH_4 is 3/4 and of C in C_2H_4 is 6/7.

Therefore the total weight of C contained in a unit weight of gas will be

$$W_3 = \frac{3/11\,A + 3/4\,E + 3/7\,F + 6/7\,G}{100}$$

Where A, E, F, and G are the per cent by weight of CO_2, CH_4, CO, and C_2H_4 from the gas analysis.

The per cent of this carbon contained in the gas as CO_2 is $\frac{3/11\,A}{W_3}$

The actual weight of this carbon will be $\frac{3/11\,A}{W_3 \times 100} \times W_2$. Since W_2 is the total weight of carbon utilized, from the fuel.

One pound of carbon on burning produces $3\frac{2}{3}$ lb. of CO_2.

$$W_2 \times \frac{3/11\,A}{W_3 \times 100} \times 3\tfrac{2}{3} = \text{total weight of } CO_2 \text{ in the gas.}$$

Let W_S = the specific weight of CO_2 at 62 deg. and 30 in. Hg. See Item 121. The standard volume V_S of CO_2 will therefore be,

$$\frac{AW_2}{100 \times W_3 \times W_S} = V_S$$

Let this volume equal a per cent (from the volumetric gas analysis) of the total volume of gas delivered by the producer. The total volume of standard gas from the gas analysis is therefore

$$\frac{100\,V_S}{a} = V'_S$$

$$V'_S = \frac{A \times W_2}{a \times W_3 \times W_S}$$

Item 126 therefore equals

$$\frac{\text{Item 144} \times (\text{Item 51} \times \text{Item 61} - \text{Item 52} \times \text{Item 68})}{0.116 \times \text{Item 135} \times (0.273 \text{ Item 144} + 0.75 \text{ Item 148} + 0.429 \text{ Item 145} + 0.858 \text{ Item 149})}$$

Item 127. Item 126 should be used as a check on Item 125. The difference between the two values should not exceed 5 per cent. Item 125 should be used in all computations.

Item 128 $= \dfrac{\text{Item 127}}{\text{hours}}$

Item 129 $= \dfrac{\text{Item 127}}{\text{Item 51}}$

Item 130 $= \dfrac{\text{Item 127}}{\text{Item 54}}$

Item 131 $=$ Item 127 $\times$ Item 121

Item 132 $= \dfrac{\text{Item 131}}{\text{hours}}$

Item 133 $= \dfrac{\text{Item 131}}{\text{Item 51}}$

Item 134 $= \dfrac{\text{Item 131}}{\text{Item 54}}$

Items 135 to 143 From chemist.

Item 104. The relative humidity, or per cent saturation is observed by means of a hair hygrometer. This may also be obtained from a wet and dry bulb thermometer, and a set of psychrometric tables.

Item 105. See Kent, page 484 for weights of air and moisture.

Let p = per cent saturation, or relative humidity, Item 104.

n = weight of moisture contained in one cu. ft. of saturated air at the observed temperature, Item 29.

$\dfrac{pn}{100}$ = weight of moisture in 1 cu. ft. of air as used.

If m = weight of 1 cu. ft. dry air at the observed temperature, then

$$\text{Item 105} = \frac{pn}{100m} \times 100 = \frac{pn}{m} = \text{Item 104} \times \frac{n}{m}$$

This formula is in error due to neglecting the vapor pressure of water; this is, however, negligible in the present case.

Item 82. Observed.

Item 83. Observed.

Item 84. = Item 82 − Item 83.

Item 86. The weight of water decomposed in the producer is evidently 9 times the weight of hydrogen formed, since 1 lb. of water on decomposition yields 1 lb. of hydrogen and 8 lb. oxygen. The total weight of hydrogen formed is equal to the total weight of free hydrogen appearing in the gas, plus the total weight of hydrogen appearing in the CH_4 in the gas, minus

the total weight of hydrogen that is not in combination with oxygen in the coal.

Item 86 therefore, equals

$$9\,\frac{\text{Item 131 (Item 147 + 0.25 Item 148)} - \text{Item 51 (Item 62} - \frac{1}{8}\text{ Item 63)}}{100}$$

Item 87. Owing to the difficulty in obtaining the weight of moisture in the gases leaving the producer with a proper degree of accuracy by the use of a dryer, it will ordinarily be better to use Item 86 for this item.

Item 106. Obtained from the gas analysis by weight, Items 144 to 152 inclusive.

Let A = per cent CO_2
B = per cent O_2.
C = N_2

Let D = per cent H_2
E = per cent CH_4
F = per cent CO

1	2	3
$C = O_2 = CO_2$	$C + O = CO$	$H_2 + O = H_2O$
$12 + 32 = 44$	$12 + 16 = 28$	$2 + 16 = 18$
$\frac{3}{11} + \frac{8}{11} = 1$	$\frac{3}{7} + \frac{4}{7} = 1$	$\frac{1}{9} + \frac{8}{9} = 1$

Fom equation (1), one lb. of CO_2 requires 8/11 lb. of O for its formation
From (2) one lb. CO requires 4/7 lb. of O for its formation.
The total amount of O appearing in 1 lb. of the gas is therefore

$$\left(\frac{8}{11}A + \frac{4}{7}F + B\right) \times \frac{1}{100}$$

This O comes from that contained in the air, that contained in the coal, and from the water decomposed. The oxygen contained in the coal, however, is supposed to be united with hydrogen, and is therefore contained in moisture, which has been allowed for in the water decomposed.

Let W = total weight of gas.

Then the total weight of O used is

$$\frac{W}{100}\left(\frac{8}{11}A + \frac{4}{7}F + B\right)$$

Let W_2 = weight of water decomposed. From (3), 1 lb. of water decomposed liberates 8/9 lb. of O.
Weight of O supplied by decomposition of water = 8/9 W_2
Let W_3 = total weight of O supplied by the air.
From the above equation we have,

$$\left(\frac{8}{11}A + \frac{4}{7}F + B\right)\frac{W}{100} = \frac{8}{9}W_2 + W_3,$$

$$\text{or } W_3 = \frac{W}{100}\left(\frac{8}{11}A + \frac{4}{7}F + B\right) - \frac{8}{9}W_2 \quad \ldots\ldots\ldots\ldots (4)$$

The weight of air used is therefore $\frac{W_3}{0.23}$, since the proportion by weight of O in air is 23, or

$$\frac{W_3}{0.23} = W_4 = \frac{1}{0.23}\left[\frac{W}{100}\left(\frac{8}{11}A + \frac{4}{7}F + B\right) - \frac{8}{9}W_3\right] \ldots\ldots (5)$$

$$\text{Therefore Item 106} = \left[\frac{\text{Item 131}}{100}\left(\frac{8}{11}\text{ Item 144} + \frac{4}{7}\text{ Item 145} + \text{Item 146}\right)\right.$$

$$\left. - \frac{8}{9} \times \text{Item 87}\right]\frac{1}{0.23} \ldots\ldots\ldots\ldots (6)$$

The above computation may be made from the weight of nitrogen appearing in the gas. The nitrogen comes from the air used and from the nitrogen introduced with the fuel.

Let C per cent per lb = weight of N_2 from analysis

Let W as before = total weight of gas.

Then $\frac{C\,W}{100}$ = total weight of N_2 in the gas.

The weight of N_2 supplied by fuel will be $\frac{W_1\,H_1}{100}$, where W_1 equals the total weight of dry coal and H_1 is the per cent by weight of N_2 contained in the coal. We have therefore,

$$\frac{CW}{100} = \frac{W_1H_1}{100} + W_4$$

where W_4 = total weight of N_2 in the air.

The weight of air supplied is therefore

$$\frac{W_4}{0.77} = \left(\frac{CW}{100} - \frac{W_1H_1}{100}\right)\frac{1}{0.77} = W_5 = \left(\frac{CW - W_1H_1}{77}\right)$$

$$\text{or Item 106} = (\text{Item 131} \times \text{Item 152} - \text{Item 51} \times \text{Item 64})\frac{1}{77} \ldots\ldots\ldots (7)$$

The weight of air derived by formula (6) will be liable to error, due principally to the error in the determination of the total quantity of water decomposed, which may be large, and also to the neglecting of the SO_2 formed.

The weight determined by formula (7) will be in error due principally to the taking of the weight of N_2 from the analysis by difference.

The results obtained from formulae (6) and (7) should check within 5 per cent.

The results obtained by (7) are believed to be more accurate and will be used in all computations.

Item 107 This may be obtained direct from the calibration curve of the orifice. It should be compared with the two values obtained above.

Item 108. This will ordinarily be taken from Item 106.

$$\textit{Item } 109 = \frac{\text{Item } 108}{\text{Hours}}$$

$$\textit{Item } 110 = \frac{\text{Item } 108}{\text{Item } 51}$$

$$\textit{Item } 111 = \frac{\text{Item } 108}{\text{Item } 54}$$

$$\textit{Item } 112 = \frac{\text{Item } 108}{\text{Item } 131}$$

$$\textit{Item } 85 = \text{Item } 84 + \text{Item } 85b + \text{Item } 85c.$$

$$\textit{Item } 85b = \frac{\text{Item } 108 \times \text{Item } 105}{100}$$

$$\textit{Item } 85c = \frac{\text{Item } 49 \times \text{Item } 50}{100}$$

$$\textit{Item } 88 = \text{Item } 85 - \text{Item } 87$$

$$\textit{Item } 89 = \frac{\text{Item } 87}{\text{Item } 85}$$

$$\textit{Item } 90 = \frac{\text{Item } 87}{\text{Item } 131}$$

$$\textit{Item } 91 = \frac{\text{Item } 87}{\text{Item } 51}$$

$$\textit{Item } 92 = \frac{\text{Item } 87}{\text{Item } 54}$$

$$\textit{Item } 93 = \frac{\text{Item } 87}{\text{Item } 108}$$

$$\textit{Item } 94 = \frac{\text{Item } 85}{\text{Item } 51}$$

$$\textit{Item } 95 = \frac{\text{Item } 85}{\text{Item } 54}$$

$$\textit{Item } 96 = \frac{\text{Item } 85}{\text{Item } 108}$$

Item 97 = Observed

Item 98 = Observed

$$\textit{Item } 99 = \frac{\text{Item } 84}{\text{Hours}}$$

$$\textit{Item } 100 = \frac{\text{Item } 99}{\text{Item } 11}$$

$$\textit{Item } 101 = \frac{\text{Item } 87}{\text{Hours}}$$

$$\textit{Item } 102 = \frac{\text{Item } 85}{\text{Hours}}$$

$$\textit{Item } 103 = \frac{\text{Item } 97}{\text{Hours}}$$

$$\textit{Item } 115 = \text{Item } 114 \times \text{Item } 121$$

$$\textit{Item } 116 = \frac{\text{Item } 98 \times 0.2205}{\text{Item } 115}$$

$$\textit{Item } 117 = \frac{100 \text{ Item } 88}{\text{Item } 131}$$

Item 153 The grate efficiency is 100 times the ratio of the total B.t.u. in the fuel minus the B.t.u. in the fuel lost through the grate; to the total B.t.u. contained in the fuel. Therefore

$$\text{Item } 153 = \frac{\text{Item } 51 \times \text{Item } 78 \times 100 - \text{Item } 52 \times \text{Item } 68 \times 14540}{\text{Item } 51 \times \text{Item } 78}$$

Item 154. The hot gas efficiency is 100 times the ratio of the total heat of combustion of the gas, plus the sensible heat of the dry gas, plus the total heat contained in the moisture, minus the heat given to the producer by the entering air, by the coal as sensible heat and by the moisture or steam in the air, or supplied from any outside source; to the heat of combustion of the dry coal. Therefore, Item 154 = $\{$Item 119 $\times$ Item 127 + Item 122 $\times$ Item 131 (Item 39 − 62 deg. + Item 88 [1116 + 0.6 (Item 39 − 212)] − Heat from external source$\}$ $\times$ 100 $\div$ Item 51 $\times$ Item 78.

The heat given to the producer by the air, moisture, coal, etc., may be neglected if the room temperature is within 20 deg. of the standard temperature 62 deg. This will ordinarily be the case. If steam is supplied to the producer by a steam nozzle taking steam from some outside source, the heat in this steam must be subtracted from the numerator of the above formula.

Item 155 The cold gas efficiency is 100 times the ratio between the total heat of combustion of the gases, to the total heat of combustion of the dry coal. That is,

$$\text{Item } 155 = \frac{\text{Item } 119 \times \text{Item } 127}{\text{Item } 51 \times \text{Item } 78} \; 100$$

$$\textit{Item } 157 = \frac{\text{Item } 156 \times \text{Item } 49}{0.02 \times \text{Item } 127}$$

$$\textit{Item } 158 = \frac{\text{Item } 97 \times 1000}{62.5 \times \text{Item } 127} = \frac{\text{Item } 97}{0.0625 \times \text{Item } 12}$$

HEAT BALANCE

DEBIT

Item 1. Obtained from Item 78.

Items 2, 3, 4, 5, 6, Using as a standard the temperature of 62 deg. fahr., the heat given to the producer by the items 2 to 6 inclusive is in most cases negligible. The error at a temperature of 100 deg. fahr. is less than 1 per cent for a producer of the contained vaporizer type. However, the formulae will be given for computation of these items.

Item 2 = Item 110 $\times$ 0.24 (Item 30 − 62°F)

Item 3 $= \dfrac{\text{Item 85b} \times (\text{H} - 1070)}{\text{Item 51}}$ where H = the total heat in 1 lb. saturated steam at the temperature of the fire room.

Item 4 $= \dfrac{\text{Item 49} \times \text{Item 50}}{100 \times \text{Item 51}}$ (Item 30 − 62 deg. fahr.)

Item 5 $= 0.24 \times$ (Item 30 − 62 deg. fahr.)

Item 6 $= \dfrac{\text{Item 82 (Item 33} - \text{62 deg. fahr.)}}{\text{Item 51}}$

CREDIT.

Item 1 = Item 122 $\times$ Item 133 $\times$ (Item 39 − 62 deg. fahr.)

Item 2 $= \dfrac{\text{Item 117} \times \text{Item 133}}{100}$ [(Item 39 − 212 deg. fahr.) $\times$ 0.6 + 1116]

Item 3 = Item 119 $\times$ Item 129

Item 4 $= \dfrac{\text{Item 52} \times \text{Item 68}}{\text{Item 51}} \times 145.40$

Item 5 This is very small and may be neglected.

Item 6 $= \dfrac{\text{Item 83}}{\text{Item 51}}$ (Item 34 − 62 deg. fahr.)

Item 7 = Sum of Items on debit side − (Item 1 + Item 2 + Item 3 + Item 4 + Items 5 and 6.)

LINE SHAFT EFFICIENCY, MECHANICAL AND ECONOMIC

By Henry Hess, Philadelphia

Member of the Society

The efficiency to be treated in this paper is that of the line shaft considered as an element for the transmission of power.

2 The complete power transmission system is made up of the shaft and pulleys; the belts, ropes or other equivalents; and the journals supporting all of these.

3 The difference between the power delivered to the system and that delivered by it is consumed in the work of bending and slipping the belts and overcoming the friction of the journals. There may be another loss due to the bending of badly aligned shafting; but as misalignment should not occur and as the remedy is obvious, it will not be considered further.

4 The power lost in the bending of the belts and in their slipping or creeping is but a small fraction of the total loss, and one, moreover, that cannot be materially lessened; assuming, of course, that belts are kept properly pliable and not allowed to dry out, become caked with dust or stiffened with adhesive dopes, all causes of loss of belt efficiency that no good shopman will allow to exist.

5 There remains the journal friction. In the average plant this accounts for nine-tenths or even more of the entire line shaft losses. Included in the journal friction are the losses at the loose pulley bearings and the countershafts.

6 The coefficient of friction of plain babbitted or of cast iron bearings ranges all the way from ½ of 1 per cent to 8 per cent. This range covers all of the many methods of lubrication in general use. The better value is rarely realized outside of the laboratory; the poorer value is by no means as rarely found as it should be. A showing of 3 per cent friction coefficient is one that the manager may well pride

All papers are subject to revision.

himself on; while a coefficient of 5 per cent is much more general, but need not, as conditions are, be taken as reflecting adversely on attention to details.

7 The remedy obviously lies in the substitution of ball bearings for plain bearings. In other fields than line shafting this remedy finds considerable employment; in some the plain bearing has indeed been superseded almost entirely. This is particularly the case where the power efficiency is of great importance, as for instance, in the automobile.

8 While some shopmen still doubt the reliability of the ball bearing, those who have followed the development of modern machinery know that hundreds of thousands of ball bearings are carrying loads varying from a few ounces to many tons, day in and day out, at speeds ranging from a few turns per minute to 10,000 or more. They realize that it is not a question of reliability *per se*, but one of selection of sizes suitable for the loads to be dealt with.

9 For line shafting it is the economic question that is to the fore. The first cost of a ball bearing installation is greater than a plain bearing equipment. Will it pay for itself by the savings effected and if so at what rate? What return on the difference in investment can be realized? That there is a saving is generally known, but accurate figures are wanted by which a manager can justify his recommendation to those who control the purse strings and are responsible for dividends.

10 When only the idle running of the line shafts is considered answers to these questions can be easily obtained, now that electric motors are so generally applied directly to line shafts and it is so simple a matter to take readings of the power delivered to them. The difference in readings for the same shafts with plain and with ball bearings represents fairly accurately the saving for the idle run.

11 But line shafts are not put up to run idly; they drive machines and these machines are sometimes heavily loaded, sometimes lightly loaded and sometimes idle. While comparative current readings taken under these conditions may be fully satisfactory to those immediately concerned, this rather crude method cannot lay claim to that accuracy which is more and more being demanded by the engineering world.

PLAN OF TESTS

12 To supply definite information the author decided that a series of comparative tests should be made, involving no variables other than the bearings themselves. In order further to eliminate possible personal bias in favor of the ball bearings the author called on Messrs. Dodge and Day to make these tests, giving them carte blanche as to methods, with instructions confined to a demand for definite and reliable figures. This investigation is the first undertaken, so far as the author

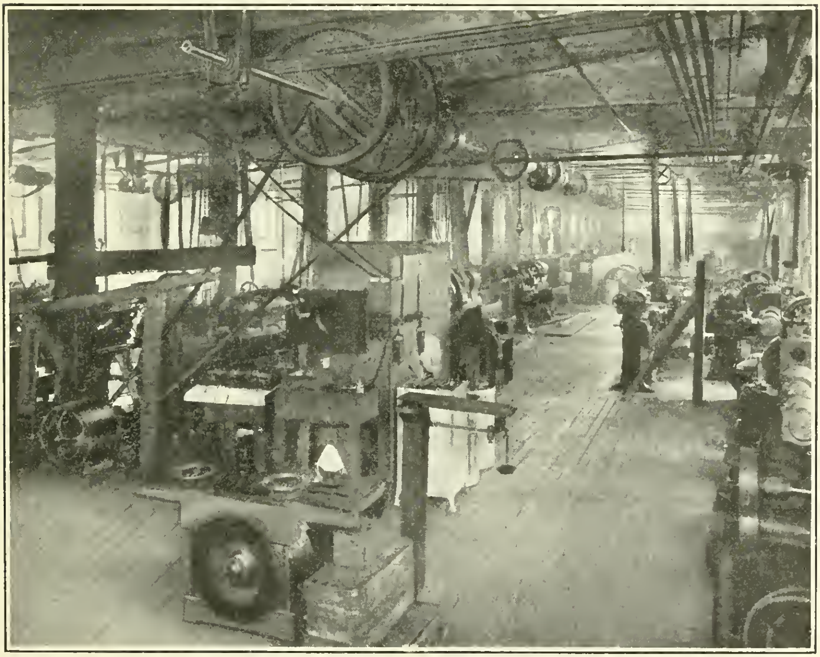

Fig. 1 View Showing Line Shafting Tested

knows, under conditions practically those of the work shop, the sole difference being the substitution of constant loads for the variables of ordinary working.

13 Besides the change in load due to the operation of the various machines driven from a line shaft, already referred to, there is the change in load due to variation in belt stress. A preliminary test quickly demonstrated that reliance could not be placed on the use of tension weighing clamps in putting on the belts. The tension was found to differ from that determined by the clamp scales. This error

could have been minimized by the use of the admirable methods and apparatus worked up by the engineers under our past-president, Fred. W. Taylor, and this plan was given serious consideration until it was found that the influence of varying humidity and temperature in the shop was such as greatly to change the tension of the belts even after they were in place.

14 The complete plan finally decided on and carried through was as follows: A line shaft of $2\frac{7}{16}$-in. diameter and 72-ft. length used

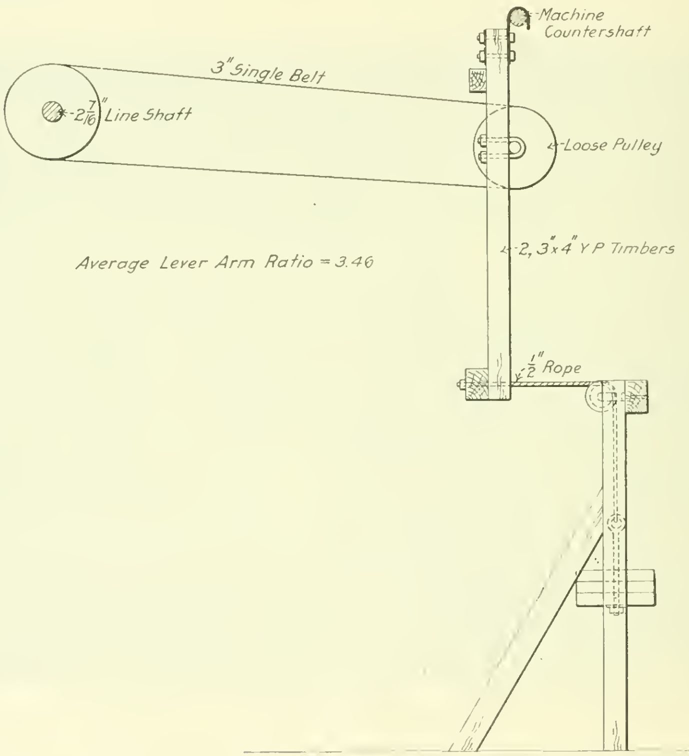

Fig. 2 Arrangement of Countershaft Frames Used During Comparative Tests of Ball and Ring-Oiling Bearings

to operate a series of heavy turret lathes was set aside for the test. This was alternately equipped with plain ring-oiling babbitted boxes and Hess-Bright ball bearings. In order to facilitate the exchange of bearings, the ball bearing boxes were placed on the shaft close to the hangers, making it necessary only to slip the plain bearings out of the hanger and slip the ball bearings in. Both types were held by the same supporting screws usual with modern hangers.

15 It is perhaps needless to mention that great care was exercised in seeing that the shaft was correctly aligned at the beginning of each test. It was supported by ten hangers, with an average

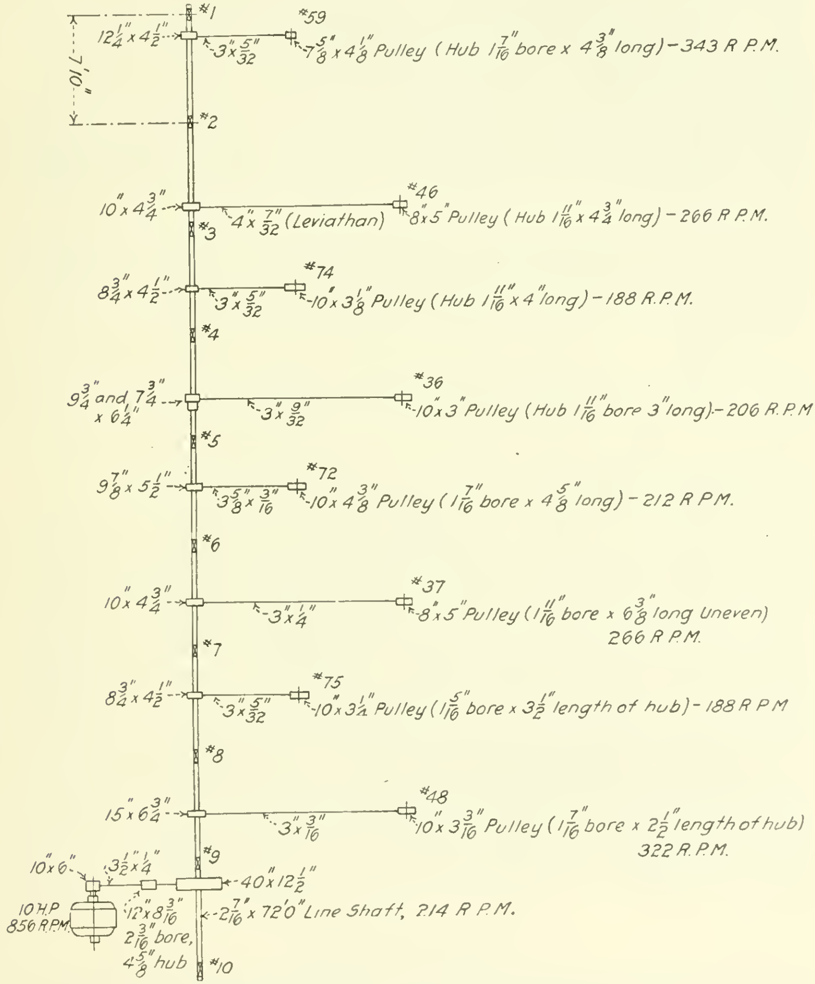

FIG. 3 ARRANGEMENT OF LINE SHAFT AND BELT DRIVES

spacing of 8 ft. See Fig. 1 to Fig. 3, the last of which shows the arrangement adopted to secure constant load.

16 The belts from the line shaft drive pulleys mounted on swings hung at their upper ends, loaded by ropes attached to their lower ends, which leads over guide pulleys to weights. The tension in the

belt is thus definitely determined by the weight and is independent of slight variatious of belt length from whatever cause. The load on the journals is therefore constant and definitely known. The only possible variable is in the friction of the loose pulleys on the swings These loose pulleys were ordinary tight pulleys picked up around the shop and arranged for oiling through the set screw holes and by the addition of channels. The friction was kept as near constant as possible by oiling at the beginning of every test. This answered fairly well except for two tests in which the rather small dimensions of the hubs gave rise to heating under the abnormally high belt tensions used.

17 Of such swings eight were employed. All were mounted on the same side of the shaft to avoid any uncertainty in load conditions that might have resulted from a possible balancing of pull from opposite sides.

18 Speeds and dimensions of shafts, pulleys, loose pulleys and loose pulley hubs, belts and belt material are marked in Fig. 2. The drive was supplied by a 10 h.p. motor from the floor. The tension of the main belt was kept constant by a weighted idler pulley bearing on its driving side.

19 Constancy of line shaft speed was assured by a rheostat inserted in the field of the 110-volt, direct-current, shunt-wound motor and the use of a Warner tachometer connected to the motor. The electrical measurements taken were the voltage across the motor terminals and ammeter readings of the armature and field currents. The electrical and mechanical losses of the motor were determined from electrical resistance and no load tests. These motor losses were deducted from the total electrical output, the balance being the power consumed by the line shaft system in journal friction, in loose-pulley hub friction, in belt bending and creep, in the motor belt tension idler and in windage. All instruments used were calibrated before and after the tests.

METHOD OF TESTING

20 The tests were divided into two duplicate series, the first, *A* with plain bearings on the line shaft; the second, *B*, with ball bearings on the line shaft. The sole variable was therefore that of the line shaft as affected by the change from plain to ball bearings.

21 In each series the effect of varying loads was determined by changing the belt tension by approximately equal increments from 20

to 90 lb. per inch width of single belt. This was supplemented by a test with all of the belts removed except the driving belt from the motor, leaving only the weight of shaft and pulleys for journal loads.

22 Each test lasted forty minutes of running time; a reading of the various instruments was taken every two minutes. That means a total of 10 hrs. 40 min. with a total of 960 recorded readings.

23 The loads on the line-shaft journals ranged from 126 to 662 lb. per journal; for the $2\frac{7}{16}$-in. by 10-in. ring-oiling babbitted bearings this gives loads ranging from 5.2 lb. to 27.3 lb. per sq. in. of projected area. For the ball bearings used, each of which had 12 balls of $\frac{9}{16}$-in. diameter, the load per ball was from 10.5 lb. to 55.2 lb.

24 It is pertinent to mention that these bearings have so far a record of nearly five years constant service under loads corresponding to about three-fourths of the maximum cited and show no evidence of wear. In that period they were lubricated but three times, once when put up, once for the test and once incidental to a shop moving.

RESULTS SHOWN BY THE TABLES

25 Details of the loading of the line shaft bearings and of the swing or countershaft idlers are given in Tables 1 and 2. Table 3 gives the averaged electrical readings for each test. Table 4 gives electrical readings with the power in kilowatts delivered to the belt and the percentage of saving due to the ball bearings. In the supplement to Table 4 is explained the derivations of the columns in Table 4 in reference to the deduction of motor losses from total input.

26 Table 4, last column, shows that the saving due to changing ten $2\frac{7}{16}$-in. plain ring-oiling babbitted bearings running at 214 r.p.m. to the ball bearings increases with increasing belt tensions from 14 per cent to 36 per cent. With the more usual belt tensions of good practice ranging from 44 lb. to 57 lb. per inch width of single belt (tests 3 and 4), the saving amounts to 36 per cent and 35 per cent.

DISCUSSION OF RESULTS

27 Tests 5 and 6 with belt tensions of 70 lb. and 83 lb. per inch width of single belt show lower savings of only 25 per cent. This falling off is due to the fact that the pressures were too high for the loose pulley hub-bearing surfaces, causing excessive heating and losses. This reduction of 25 per cent does not indicate a smaller actual saving due to the ball bearings, but simply that the increase was due to

TABLE 1 RESULTANT PRESSURES ON LINE SHAFT BEARINGS

Bearing No.	Line Shaft Dead Loads at Bearings Lbs.	Components of Belt Loads at Bearings (Lbs.) Test Number 1	2	3	4	5	6	Resultant Loads at Bearings (Lbs.) Test Number 1	2	3	4	5	6	Belt Number Corresponding to Bearing Loads
1	80.33	87.5	153.6	219.1	284.8	350.4	416.5	126	181.5	241.5	303.3	367.5	433	59
		23.7	41.6	59.4	77.2	95.1	113.0							59
2	132.63	41.8	73.5	104.7	136.0	167.8	199.0	150.5	183.5	219	258	304.5	347.5	46
		39.4	121.7	173.8	226.0	277.7	330.5							46
3	180.17	48.6	85.3	121.6	158.0	195.0	231.0	222.5	282.5	358	436	520	604	74
4	220.57	62.6	109.9	156.9	204.0	250.5	298.5	261	324.5	402	480	567	662	74
		65.3	114.6	163.7	212.8	261.5	315.5							36
5	182.16	45.9	80.6	114.8	149.2	184.0	214.0	218	273.5	340	406	488	567	36
		63.1	110.7	158.2	205.5	252.8	301.0							72
6	190.09	48.1	84.5	120.3	156.5	192.7	228.5	221.5	268	324.5	390	456	523	72
		52.7	92.5	132.0	171.7	211.2	250.5							37
7	201.83	58.5	102.7	146.5	190.5	234.3	279.0	245	305.5	380.5	460	545	635.5	37
		63.7	111.8	159.7	207.5	255.0	303.7							75
8	183.96	47.5	83.4	118.8	154.5	190.5	225.8	215	262	321	385	452	520	75
		52.7	92.5	132.0	171.5	211.0	250.5							48
9	317.14	58.5	102.7	146.5	190.5	234.5	279.0	505	496	490	489	492	500	48
		260	260	260	260	260	260							Motor Belt
10	138.71	60	60	60	60	60	60	185	185	185	185	185	185	Motor Belt
Total	1828.00	1210	1882	2548	3216	3884	4556	2350	2762	3262	3793	4377	4977	

TABLE 2 RESULTANT PRESSURES ON COUNTER SHAFT IDLERS

Pulley No.	Weight of Pulley and Half of Belt Lbs.	Belt Pulls on Idler Pulleys — Test Number 1	2	3	4	5	6	Resultant Pressures on Idlers — Test Number 1	2	3	4	5	6	R.P.M. of Idlers	Angle of Inclination of Belt from Horizontal
59	9.6	111.2	195.2	278.5	362.0	445.5	529.5	111.0	194.5	277.0	360.8	444.2	528.0	343	5° 38′
46	19.0	"	"	"	"	"	"	111.7	195.5	278.0	361.6	445.0	528.5	266	1° 16′
74	11.6	"	"	"	"	"	"	110.8	194.2	277.3	360.5	444.5	527.5	188	6° 41′
36	13.8	"	"	"	"	"	"	111.7	195.5	278.0	361.8	445.0	528.5	206	1° 55′
72	14.9	"	"	"	"	"	"	110.7	194.0	277.0	360.5	444.0	527.0	212	6° 51′
37	12.2	"	"	"	"	"	"	111.7	195.5	278.1	361.8	445.0	528.5	266	2° 0′
75	11.6	"	"	"	"	"	"	110.8	194.2	277.3	360.5	444.5	527.5	188	6° 30′
48	13.2	"	"	"	"	"	"	111.8	195.6	278.2	361.7	445.2	529.0	322	1° 16′
Average								111.3	194.9	277.6	361.2	444.7	528.1		
Motor															136° 0′0″

TABLE 3 AVERAGE ELECTRICAL READINGS FOR EACH TEST

Test No.	Date 1908	Total Resultant Loads on Lineshaft Bearings Lbs.	Ave. Resultant Pressures on Idlers Lbs.	Total Kw. Taken from Line	Supply Pressure Volts	Ave. Armature Current Amperes	Ave. Field Current Amperes
1*A*	2/4	2349.5	111.3	1.375	111.0	10.43	1.96
1*B*	2/6			1.302	109.6	10.1	1.79
2*A*	2/4	2762	194.9	1.560	109.5	12.3	1.92
2*B*	2/6			1.372	109.5	10.75	1.78
3*A*	2/4	3261.5	277.6	1.842	109.6	14.9	1.95
3*B*	2/6			1.516	110.0	12.0	1.82
4*A*	2/4	3792.5	361.2	2.051	108.6	17.1	1.82
4*B*	2/6			1.653	110.0	13.25	1.81
5*A*	2/4	4377	444.7	2.098	110.5	17.1	1.91
5*B*	2/7			1.802	109.4	14.7	1.81
6*A*	2/4	4977	528.1	2.238	109.9	18.4	1.92
6*B*	2/7			1.933	110.0	15.8	1.78
7*A*	2/1	2000	0	0.479	110.0	4.00	0.366
7*B*	2/6			0.381	103.0	3.33	0.381
8*A*	2/4	2070	0	1.107	111.0	8.00	1.98
8*B*	2/7			0.955	110.0	6.75	1.93

Tests 7*A* and 7*B* made with 1-h.p. motor. All other tests made with 10-h.p. motor. Motor, 856 r.p.m. Line shaft 214 r.p.m.

TABLE 4 ELECTRICAL READINGS, NEW POWER IN KILOWATTS, AND PERCENTAGE OF SAVING DUE TO BALL BEARINGS

Test No.	Total Kw. Taken from Line	Ave. Line Volts	Ave. Field Current	Ave. Field Watts	Watts Delivered to Armature	Armature and Brush Resistance Loss	Armature and Brush Drop	Load + Iron Loss at Apx. Speed	$\frac{\text{E.M.F. at 856 r.p.m.}}{\text{E.M.F. in experiment}}$	Load and Motor Iron Loss (856 r.p.m.)	Iron Loss + Pulley Bearing Loss	Kw. Delivered to Belt at 856 r.p.m.	% Saving
1*A*	1.375	111.0	×1.96	=217	1158	11	1.0	1147	$\times\frac{106.6}{110}$	=1112	586+60	0.466	14
1*B*	1.302	109.6	×1.79	=196	1106	10	1.0	1096	$\times\frac{100.7}{108.6}$	=1016	554+60	0.402	
2*A*	1.560	109.5	×1.92	=210	1350	15	1.2	1335	$\times\frac{105.2}{108.3}$	=1297	579+60	0.660	29
2*B*	1.372	109.5	×1.78	=195	1177	12	1.2	1165	$\times\frac{100.4}{108.4}$	=1079	552+60	0.467	
3*A*	1.842	109.6	×1.95	=214	1628	22	1.5	1606	$\times\frac{106.3}{108.1}$	=1579	585+60	0.934	36
3*B*	1.516	110	×1.82	=200	1316	14	1.2	1302	$\times\frac{101.8}{108.8}$	=1218	560+60	0.598	
4*A*	2.051	108.6	×1.82	=198	1853	29	1.7	1824	$\times\frac{101.8}{106.9}$	=1737	560+60	1.117	35
4*B*	1.653	110	×1.81	=199	1454	18	1.3	1436	$\times\frac{101.4}{108.7}$	=1340	558+60	0.722	
5*A*	2.098	110.5	×1.91	=211	1887	29	1.7	1858	$\times\frac{104.9}{108.8}$	=1791	557+60	1.154	25
5*B*	1.802	109.4	×1.81	=198	1604	22	1.5	1582	$\times\frac{101.4}{107.9}$	=1487	558+60	0.869	
6*A*	2.238	109.9	×1.92	=211	2027	34	1.8	1993	$\times\frac{105.2}{108.1}$	=1940	579+60	1.301	25
6*B*	1.933	110	×1.78	=196	1737	25	1.6	1712	$\times\frac{100.4}{108.4}$	=1586	552+60	0.974	
7*A*	0.479	110	×0.366	= 40	439	48	12.0	391	$\times\frac{92.5}{98}$	= 369	76+25	0.268	21
7*B*	0.381	103	×0.381	= 39	343	34	10.1	309	$\times\frac{95.4}{92.9}$	=317	81+25	0.211	
8*A*	1.107	111	×1.98	=220	887	6	0.8	881	$\times\frac{107.3}{110.2}$	=858	590+60	0.208	65
8*B*	0.955	110	×1.93	×212	743	5	0.7	738	$\times\frac{105.6}{109.3}$	=713	581+60	0.072	

SUPPLEMENT TO TABLE 4

For 10-h.p. motor : armature resistance = 0.04 ohms, and brush contact resistance = 0.05 ohms to 0.06 ohms (2.5 sq. in.) for current densities not greater than 7.5 amperes per sq. in,; hence drop in armature and brush contact = 0.1 ohms × armature current, also loss in armature resistance and brush contact resistance = 0.1 ohms × (armature current).[2]

Iron loss = 5.5 amperes × e.m.f.

E.m.f. with 1.6 amperes in field $= (94 - 0.5)\frac{856}{850} = 94.2$; with 2.0 field amperes $= (108 - 0.5)\frac{856}{852} = 108.$

E.m.f. with any field current at 856 r.p.m. $= 94.2 + 13.8 \times \frac{\text{field current} - 1.6}{0.4}.$

For 1 h.p. motor (tests 7*A* and 7*B*): armature resistance = 2.5 ohms, and brush contact resistance $= 0.85$ ohm $\left(\frac{5}{16}\text{ sq. in.} \times \frac{1}{2}\right)$, only half of brush in contact; drop in brush contact for 4 amperes (7*A*) = 2 volts, and for 3.33 amperes (7*B*) = 1.8 volts.

Iron loss $= \left(0.80 + 0.1 \times \frac{\text{field current} - 0.35}{0.7}\right)$ e.m.f.

E.m.f. with 0.35 amperes in field $= (95 - 0.8 \times 3.35)\frac{856}{884} = 89.4$ volts; with 0.42 field current $- (109 - 3.1)\frac{856}{880} = 103$ volts.

E.m.f. with any field current $= 89.4 + 13.6 \times \frac{\text{field current} - 0.35}{0.7}.$

improper excessive friction in the loose pulley hubs, particularly during the "B" runs. The pressure on the smallest countershaft pulley bearing surface during these tests, Nos. 5 and 6, rose to 124 lb. and 148 lb. per sq. in. of projected area, respectively, which are excessive values.

28 Tests 7 and 8 were with all the belts off and the line shaft journals consequently sustaining only the weight of the shaft and pulleys and the pull of the one driving belt. The great discrepancy between a saving of 21 per cent and 65 per cent for apparently similar conditions needs explanation. Test 7 was made with a small 1-h.p. motor; for test 8 the same 10-h.p. motor used for the other tests was employed. On subsequent examination it was found that the small motor bearings were badly in need of oil and quite hot. A no load reading of this motor showed 250 watts, which dropped to 100 watts after oiling, a difference of 0.15 k.w. Deducting this from the readings of 0.268 and 0.211 gives 0.118 and 0.061, the latter representing a saving of 52 per cent which compares reasonably well with test 8.

DERIVATION OF CONSTANTS FOR USE IN ESTIMATING LOSSES

29 While the conditions of loading in this series of tests certainly include those of general practice and it may thus be safely inferred that the savings here shown may be generally realized, it is still desirable to derive constants that may be applied to any set of conditions.

30 The losses incurred are: Line shaft journal friction; countershaft journal friction; belt slip and resistance to bending; belt and pulley windage. The last two may be safely neglected as not being a serious percentage of the total power losses under the average shop conditions although they may become a serious percentage under very light loads.

31 For good ball bearings the coefficient of friction is known to be close to 0.0015. For plain bearings the coefficient of friction may be taken at an average value of 0.03 under good conditions. For plain countershaft bearings the coefficient of friction may also be taken at an average value of 0.03 under good conditions.

32 Under the conditions of this test the countershaft bearings were replaced by the hubs of loose pulleys on the swings. With the very primitive oiling conditions and the rather high pressures the coefficient of friction here may be safely taken as high as 0.08.

Let L = load in pounds.
d = shaft. diameter in inches.
S = shaft speed in r.p.m.
μ_p = 0.03 = coefficient of friction for plain ring oiling bearings.
μ_l = 0.08 = coefficient of friction for loose pulley bearings.
μ_b = 0.0015 coefficient of friction for ball bearings.
kw. = power consumed in kilowatts.

$$\text{Kw.} = \frac{0.746\,\pi\,d\,L\,S\,\mu}{12 \times 33000}$$
$$= 0.000{,}0059\,L\,d\,s\,\mu$$

and for $d = 2\frac{7}{16}$ in., $S = 214$; Kw. $= 0.00308\,L\mu$.

33 This works out for the various total loads (Table 4) of the six tests:

LINE SHAFT LOSSES IN KILOWATTS

Load in pounds	2350	2762	3262	3793	4377	4977
Plain Bearings, Kw	0.217	0.255	0.301	0.350	0.405	0.460
Ball Bearings, Kw	0.011	0.013	0.015	0.018	0.020	0.023

34 The loose pulleys on the countershafts had various diameters and speeds, given in Fig. 2. The sum of the products of these corresponding diameters and speeds is 3060. For this, kw. = 0.018 $L\mu$. This works out for the various average loads (Table 5) of the six tests:

COUNTERSHAFT LOSSES IN KILOWATTS

Loads in pounds	111.3	194.9	277.6	361.2	444.7	528.1
Countershaft, Kw	0.160	0.280	0.400	0.520	0.640	0.760

35 Adding these countershaft losses to the plain and then to the ball bearing losses above gives

TOTAL LOSSES

Plain Bearings, Kw	0.377	0.535	0.701	0.870	1.045	1.220
Ball Bearings, Kw	0.171	0.293	0.415	0.538	0.660	0.783

COMPARISON OF ACTUAL AND CALCULATED LOSSES

36 In order to make convenient comparisons of these calculated losses with those found by measurement they are tabulated and compared as follows:

TOTAL LINE AND COUNTERSHAFT POWER SAVINGS COMPARED

Tests	1	2	3	4	5	6
Plain bearings, calculated, Kw	0.377	0.535	0.701	0.870	1.045	1.220
Ball " " "	0.171	0.293	0.415	0.538	0.660	0.783
Calculated savings due to ball bearings, Kw	0.206	0.242	0.286	0.332	0.385	0.437
Savings expressed as per cent	55	45	41	38	37	36
Plain bearings, measured Kw	0.466	0.660	0.934	1.117	1.154	1.301
Ball " " "	0.402	0.467	0.598	0.722	0.869	0.974
Measured savings due to ball bearings Kw	0.064	0.193	0.336	0.395	0.285	0.327
Savings expressed as per cent	14	29	36	35	25	25

37 A comparison of the calculated per cent of saving with the measured per cent of saving as given in the preceding table shows a fair correspondence in tests 3 and 4 but a considerable divergence for tests 1—2—5—6. Now 1 and 2 are for very light loads and the difference may probably be accounted for as due to the neglected belt resistances and windage. As these are constant and probably independent of the load, they are a large factor for light loads and less so for heavier loads.

38 Tests 5 and 6 showed abnormal losses in the countershafts, accounted for by serious overheating of the loose pulley hubs.

CONCLUSIONS FROM TESTS MADE UNDER NORMAL BELT CONDITIONS

39 Fortunately tests 3 and 4 were made under conditions of normal belt tensions of 44 and 57 lb. per inch width of single belt and so indicate that the

a Savings due to the substitution of ball bearings for plain bearings on line shafts may be safely calculated by using 0.0015 as the coefficient of ball bearing friction, 0.03 as the coefficient of line shaft friction, and 0.08 as the coefficient of countershaft friction.

b When the belts from lineshaft to countershaft pull all in one direction and nearly horizontally the saving due to the substitution of ball bearings for plain bearings on the lineshaft may be safely taken as 35 per cent of the bearing friction.

c When ball bearings are used also on the countershafts the savings will be correspondingly greater and may amount to 70 per cent or more of the bearing friction.

d These percentages of savings are percentages of the friction work lost in the plain bearings; they are not percentages of the total power transmitted. The latter percentage will depend upon the ratio of the total power transmittted to that absorbed in the line and countershafts.

e The power consumed in the plain line and countershafts varies, as is well known, from 10 to 60 per cent in different industries and shops. The substitution of ball bearings for plain bearings on the line shaft only, under conditions of paragraph "*a*" will thus result in savings of total power of $35 \times 0.10 = 3.5$ per cent to $35 \times 0.60 = 21$ per cent. By using ball bearings on the countershafts, also the saving of total power will be from $70 \times 0.10 = 7$ percent to $70 \times 0.60 = 42$ per cent.

EXPENDITURE REQUIRED TO EFFECT POWER SAVING

40 While power saving is of interest and desirable the man responsible for the earning of dividends will want to know what it costs to bring about such power saving and what the investment involved will pay.

41 A reference to the bearing cost of this test will give the answer.

Ten $2\frac{7}{16}$-in. by 16-in. drop ball bearing hangers, ocmplete cost........			\$212.60
Ten $2\frac{7}{16}$-in. by 16-in drop ring oiling hangers, complete cost..........			84.00
	Extra investment		\$128.60
Value of saving of 0.395 kw. at 3 cents per kw.-hour for 3000 hr. per year..			\$35.50

(Conditions of test No. 4 representing average)

This saving represents on the extra investment................27 per cent

A closer calculation, taking into account all of the elements, shows a still better result:

First cost, plain bearing installation, \$84.00			
Depreciation at 20 years........................		\$4.20	
Maintenance Oil; $\frac{1}{2}$ pt. per day at 20 cents per gal............		3.75	
Labor, 2 hr. per week at 20 cents........................		20.80	
	Total		\$28.75
First cost ball bearing installation, \$212.60			
Depreciation at 20 years........................		10.13	
4 per cent interest on first cost difference..................		5.15	
Maintenance:			
Oil, 1 gal. per year................................		.20	
Labor, 5 hr. once per year.........................		1.00	
	Total		16.48
	Difference		\$12.27
Value of power saving of 0.395 kw. at 3 cents per kw.-hr. for 3000 hr....			35.50
	Annual saving total		\$47.77

Annual saving as return on extra investment of \$128.60 = 37 per cent

AN ELECTRIC GAS METER

By Prof. Carl C. Thomas, Madison, Wis.
Member of the Society

The meter described in this paper is designed for measuring the rate of flow of gas, air or steam. The operation of the meter depends upon the principle of adding electrically a known quantity of heat to the gas and determining the rate of flow by the rise in temperature of the gas between inlet and outlet of the meter. This principle lends itself to the operation of a meter possessing the following characteristics:

a There are no moving parts inside the meter or in contact with the gas.

b The accuracy of the meter and its sensitiveness are independent of the rate of flow of gas, and of fluctuations in pressure and temperature.

c The meter may be used to measure gas at high pressure as well as at low pressure, and is independent of small fluctuations in pressure, such as those in the discharge from an air compressor or in the suction of a gas engine.

d The meter produces a continuous autographic record showing the rate of flow and its variation.

e Meters of comparatively very small size have very large capacity.

f The meter may be opened for inspection, for blowing out accumulated matter with an air blast, or for washing with gasolene, and it can be dismantled to any extent desired without interfering with the operation of the plant.

2 Fig. 1 shows the meter as constructed for gas or air measurement, and Fig. 2 shows the exterior of the meter, of which Fig. 1 is a section. The meter consists of two parts, first, the measuring element *A* (Figs. 1, 3 and 4), through which all the gas passes when the

All papers are subject to revision.

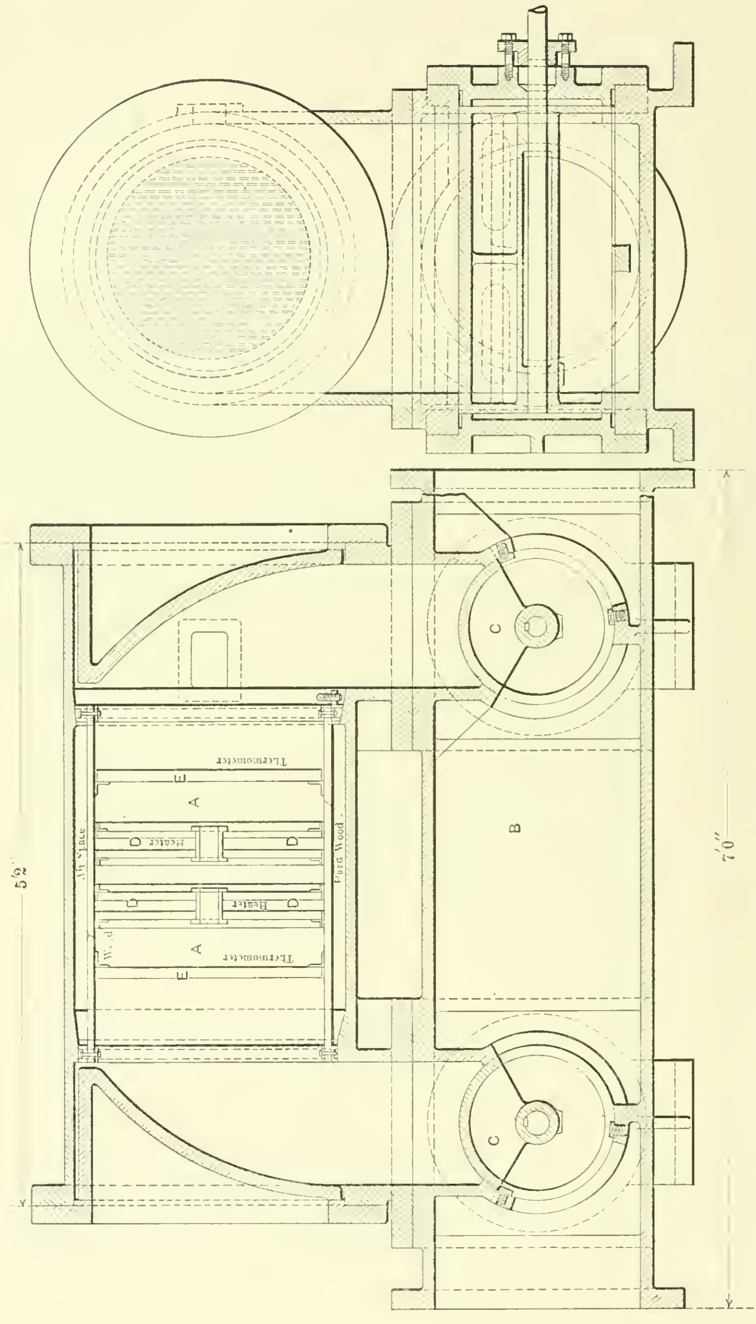

Fig. 1. Longitudinal and Cross Sections of Electric Gas Meter, Showing Construction for Measuring Air or Gas

meter is in operation; and second, a by-pass, B (Fig. 1), so arranged that the meter can be readily cut off from the gas main by operation of the valves C, when it is desired either to operate without the meter for the purpose of inspecting or cleaning out, or to cut the meter out altogether for any reason. In certain classes of gas work, rolling valves, such as are shown at C, have been found to give trouble, while in other classes of work they are satisfactory. The gate valves customarily used in gas work can be substituted for rolling valves as occasion requires, and the by-pass can be made up of ordinary pipe and fittings instead of being a part of the meter.

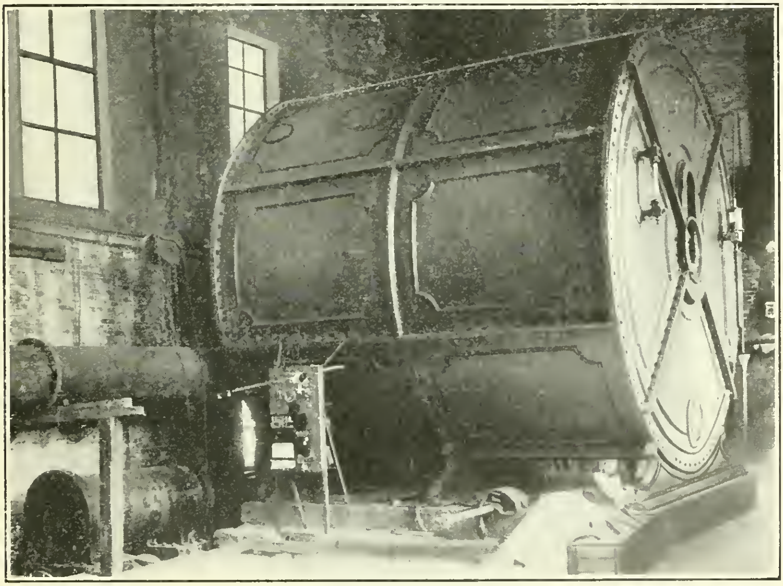

Fig. 2 View Showing the Comparative Size of the Thomas Electric Gas Meter (at the Lower Left-Hand Corner) and the Ordinary Wet Gas Meter of the Same Capacity

3 The meter consists of an electric heater D (Fig. 1 and Fig. 4), formed of suitable resistance material disposed across the gas passage in such a way as to impart heat uniformly and at a regular rate to the gas passing through the meter. The temperature of the gas is thus raised from that at entrance to some higher exit temperature, and the rise of temperature is measured and autographically recorded by means of the two electrical resistance thermometers E (Fig. 1 and Fig. 4), on the two sides of the heater.

4 These thermometers consist of wire wound upon vertical tubes so disposed as to come in contact with all the gas passing through the meter, thereby indicating the average temperature over the cross section of the gas passage. The fifteen tubes shown at the right of Fig. 1, and also shown in Fig. 3 and Fig. 4, extending in a vertical direction over the cross-section of the meter, support the resistance wire of the thermometers so as to afford a rugged construction. These

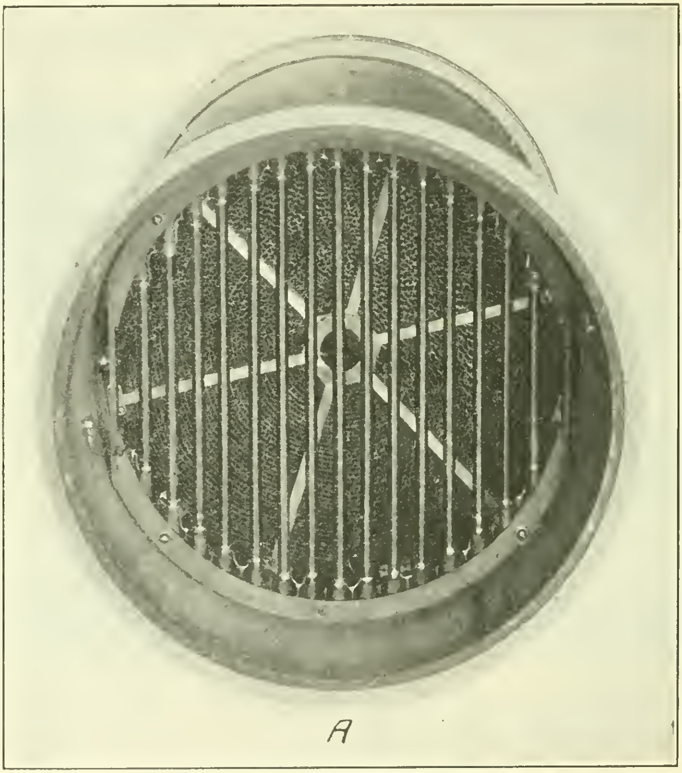

Fig. 3 Heater Unit and One of the Resistance Thermometers

thermometers are connected to a recorder (Fig. 2 and Fig. 5), which draws a line on a chart and thus indicates the difference of temperature between the two thermometers.

5 A typical diagram is shown in Fig. 6. This diagram represents a gas flow of from 90,000 to 85,000 cu. ft. per hr., taken during a portion of the day when the fluctuation in flow is small, but nevertheless

continuous. Every small fluctuation in quantity of flow is recorded on the diagram.

6 The diagram in Fig. 7 was made during a period in which the flow varied extensively, the smallest amount recorded being about 17,000 cu. ft. per hr., increasing to 45,000, then to 62,000, to 75,000, the record ending at a flow of about 32,000 cu. ft. per hr.

7 The record in Fig. 6 was made with a temperature difference of about 4 deg. fahr. between the two thermometers, and an energy input of approximately 2 kw. The energy input when the record

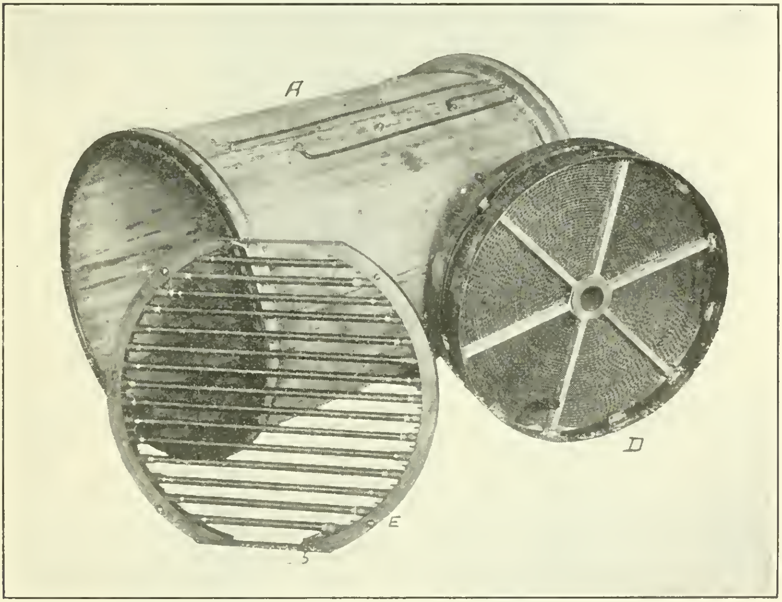

Fig. 4 Showing Construction of Heater and Thermometers

in Fig. 7 was made was approximately 1.15 kw. Fig. 6 is a typical record for a meter of normal capacity of 100,000 cu. ft. per hr., with an electric input of 2 kw.

8 The principle underlying the measurement of gas by this means is as follows: If gas is flowing through the heater at a given uniform and constant rate, and if heat is being supplied electrically, and imparted to the gas at a constant rate, a certain definite rise of temperature will be produced in the gas during its passage between the two thermometers and through the heater, and this constant difference

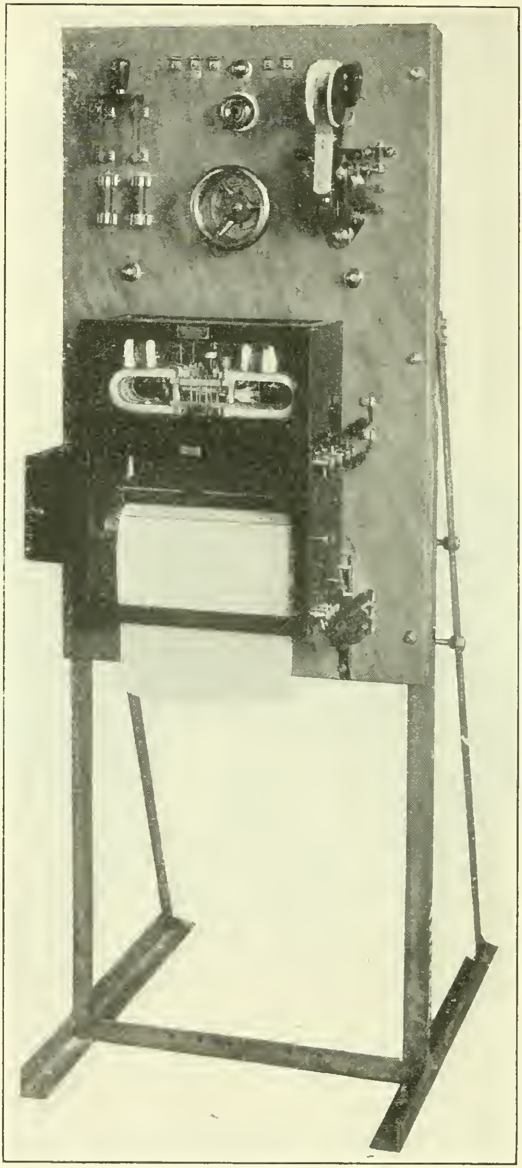

Fig. 5 Recording and Operating Instrument

of temperature will be maintained so long as the amount of gas passing per unit of time is constant. But if the quantity of gas passing per unit of time diminishes, the heat supplied at the same constant rate as before will raise the temperature of the gas by a greater amount than was the case when a larger quantity of gas was flowing and absorbing the energy liberated by the heater. Conversely, if the rate of flow increases, the energy being supplied to the heater and delivered to the gas will not be able to raise the temperature by as great an amount as when the rate of flow was less. The temperature difference produced by a known input of electrical energy thus forms a measure of the quantity of gas flowing through the meter.

9 The meter may be operated in either one of two ways, of which the first is as follows: the difference of temperature between inlet and

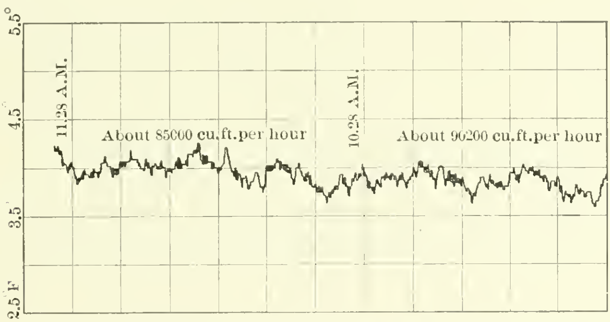

Fig. 6 Autograph Record Showing Gas Flow of about 87,000 cu. ft. per Hour

NOTE: THIS DIAGRAM WAS TAKEN UNDER APPROXIMATELY STEADY CONDITIONS OF FLOW DURING THE REGULAR OPERATION OF ONE OF THE PLANTS OF THE MILWAUKEE GAS LIGHT COMPANY. THE PAPER IN THIS CASE WAS TRAVELING AT A RATE OF 3 IN. PER HOUR. THE RECORDER CAN BE SET FOR ANY ONE OF THREE SPEEDS OF PAPER, 3 IN., 6 IN., OR 12 IN. PER HR. THE HIGHER SPEEDS ARE DESIRABLE AS THEY SMOOTH OUT THE CURVE OF TEMPERATURE DIFFERENCES. THE SCALE OF TEMPERATURE DIFFERENCES CAN ALSO BE GREATLY ENLARGED IF DESIRED.

outlet is kept constant, and the watts required to maintain this constant difference of temperature vary directly as the weight of flow. The watts input thus forms the measure of the weight of flow of air or gas, the watts being measured by a recording wattmeter, or in some cases by an integrating wattmeter. The fixed difference of temperature (about 5 deg. fahr.) is maintained by the action of a device made upon the same principle as the well-known autographic temperature recorders used in connection with resistance thermometers, but without the autographic part.

10 The mechanism which actuates the pen carriage in the autographic recorder is so arranged that when the carriage tends to depart from the straight-line path indicating a constant difference of temperature it automatically cuts in and out the resistance necessary in order to maintain the fixed difference of temperature. This variation of energy input is accomplished by a small motor-controlled rheostat mounted on the switchboard. Thus as the rate of flow of gas is increased, the temperature difference tends to decrease, and at once additional energy is introduced sufficient to heat the increased weight of gas so as to maintain the constant temperature difference. This method of operation is advantageous because it does not require the maintenance of a constant voltage on the line supplying the energy for heating the gas. The accuracy is thus independent of the small fluctuations in voltage generally found on electric supply circuits.

11 The second method of operation involves the use of the autographic temperature recorder, including the graphical part, the diagram from which, representing the variation of difference of temperature with constant energy input, gives the measure of the quantity of gas passing the meter. That is, the electrical resistance of the meter remains constant, and the meter is supplied with current at constant voltage, which results in constant energy dissipation in the meter. The difference of temperature between inlet and outlet then rises and falls according to the decrease or increase, respectively, of the rate of flow of gas.

12 The first method of operation mentioned is superior to this second method, inasmuch as the first is independent of any change which might take place in the electrical resistance of the material composing the heater. Operation by the second method requires that constant voltage be maintained across the line, and that the electrical resistance of the heater shall remain constant, or else that both watts input and temperature difference shall be recorded. In the experimental work of developing the meters it has been found convenient to use this second and more cumbrous method, but in meters at present under construction the first-mentioned method has been adopted, thus avoiding the necessity for either constant voltage or constant resistance, and resulting in simpler apparatus throughout. A record of the watts input is, by the method now used, all that is required for determining the flow of gas through the meter. The meters can be arranged to operate with either direct or alternating current, and the controlling device can be arranged to work with any desired voltage.

13 Fig. 2 shows, at the lower left-hand corner, an electric gas meter together with its autographic recorder and switchboard control. This electric meter is used for measuring all of the gas which was formerly passed through the large wet meter shown in the figure, and is of sufficient capacity to enable it to measure about three times the amount of gas for which the wet meter is suited. The electric meter was placed in this position between a 100,000 cu.ft. gas holder and the large station wet meter, for the purpose of calibrating the electric meter and comparing the results, based upon the rate of drop of the gas holder, with the readings of the wet meter. The curve obtained from the autographic recorder was thus interpreted by means of the calibration carried on in connection with the gas holder, the wet meter and a meter prover of the largest size made. It was found that the wet meter used in this case was exceedingly accurate. It had been carefully put in order and calibrated before these tests, and when operated at loads within its capacity, the readings were entirely reliable. The best evidence of this is given by the results used in plotting Fig. 8.

14 The specific heat of a given kind of gas appears to be very nearly constant, since those constituents which vary from time to time are not those which appreciably affect the value of the specific heat. But it is desirable to calibrate the meters with a gas having the same specific heat as the gas which it is intended to measure in a particular case. The specific heat of illuminating gas is very closely 0.020 per cu. ft. at atmospheric pressure, as shown by Fig. 8 and also by the following calculation based upon a fairly typical analysis. Such variation as commonly occurs in the relative amounts of the various constituents does not materially affect the specific heat.

	Vol. cu. ft.	Weight per cu. ft., lb.	Total Weight lb.	Specific Heat per lb.	Specific Heat per cu. ft.
CO_2	0.04	0.11637	0.004658	0.216	0.00100
C_2H_4	0.11	0.0741	0.00815	0.404	0.00329
O_2	0.001	0.08463	0.00085	0.217	0.00023
CO	0.331	0.07407	0.02450	0.245	0.00600
CH_4	0.1761	0.04234	0.00746	0.593	0.00442
H_2	0.303	0.00530	0.00160	3.409	0.00546
N_2	0.0389	0.07429	0.00289	0.244	0.00071
					0.02111

15 The specific heat of blast-furnace gas is practically the same as that of atmospheric air, and the same is true in a general way regard-

ing producer gas. Thus, taking the following as an average analysis of blast-furnace gas, the specific heat is found to be 0.0192, while atmospheric air has a specific heat almost identical with this, or approximately 0.0191 per cu. ft. This is to be expected, since producer gas and blast-furnace gas consist principally of nitrogen and carbon monoxide.

	Vol. cu. ft.	Weight per cu. ft., lb.	Total Weight lb.	Specific Heat per lb.	Specific Heat per cu. ft.
N_2	0.60	0.0743	0.0446	0.244	0.0109
CO	0.24	0.0741	0.0178	0.245	0.0044
CO_2	0.12	0.1164	0.0140	0.216	0.0030
H_2	0.02	0.0053	0.0001	3.409	0.0003
C_2H_4	0.02	0.0741	0.0015	0.404	0.0006
					0.0192

16 The meters have been calibrated with illuminating gas and with air. A certain amount of water vapor is carried with the gas or air passing the meter. This vapor forms part of the gas or air, and is heated just as are the other constituents. The rise of temperature caused by the heat added in the meter is only a few degrees, and consequently the water vapor does not experience a change of state. The temperature of the metal forming the electric heater rises only 15 or 20 deg. fahr. above the temperature of the gas. The question of latent heat of vaporization of the water vapor therefore does not enter into the considerations underlying measurement of the gas.

17 While calibration of the meters under actual conditions of service is depended upon to obtain quantitative results, yet these meters are of such a nature that the quantity of gas or air passing through them can be very closely calculated from a knowledge of the energy input and the specific heat of gas or air. This fact, that the quantity of flow can be quite closely calculated, independently of a calibration curve, makes it possible to check the accuracy of the readings obtained.

18 The development of this meter is a result of experiments which the writer has been making for some years to determine the specific heat of gases by heating them electrically. The performance of a properly constructed heater for this purpose proved to be so entirely regular that it was apparent that the quantity of gas flowing through it could be very accurately measured by the method now used in these meters. The problem is thus the reverse of the problem of determining specific heat by measurement of the electrical energy necessary to heat the gas. It will be seen by reference to Fig. 1 that

the whole process of heating the gas and of measuring the difference of temperature between inlet and outlet, is accomplished in a relatively small space which is well insulated so far as heat losses are concerned, since the heater and thermometers are contained in a casing

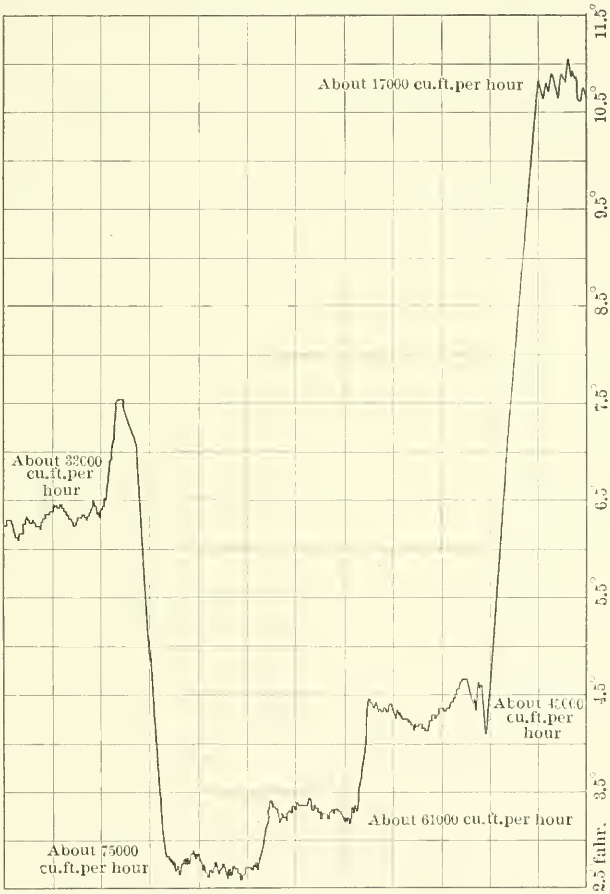

Fig. 7 Autograph Record Showing Wide Fluctuations in Flow of Gas

made of hardwood strips and separated from the metallic walls of the meter by an air space.

19 A typical calibration curve is shown in Fig. 8. The curve shows the degrees rise in temperature per kilowatt introduced when any given rate of flow through the meter is taking place. It will be seen that this curve is asymptotic to the coördinate axes, because,

when an indefinitely great amount of gas is being heated, any finite input of heat will produce only an indefinitely small rise of temperature; and on the other hand, when the amount of gas becomes indefinitely small, a finite input of heat will cause an indefinitely great rise of temperature. The calibration curves obtained are therefore rectangular hyperbolas. The product of weight of gas multiplied by degrees temperature rise per watt introduced is a constant, and this

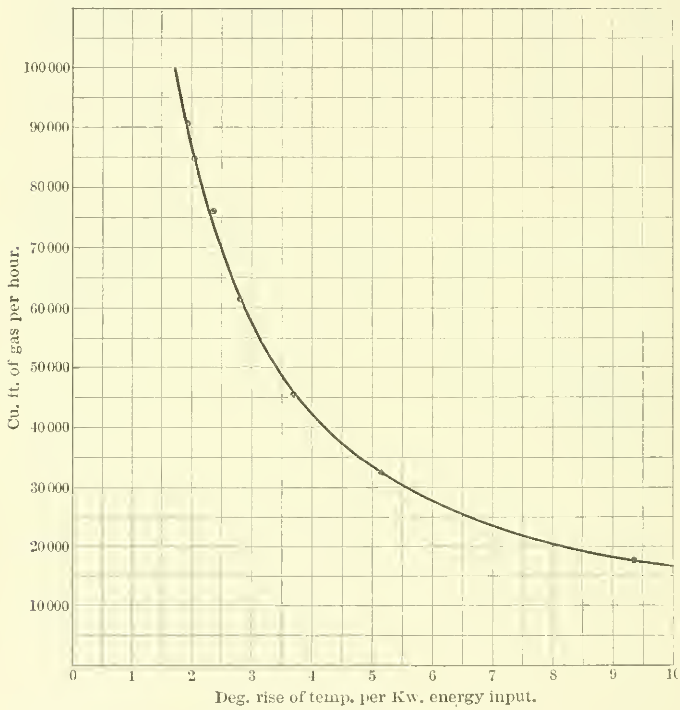

Fig. 8 Calibration Curve, See Appendix for Data

constant, for a given kind of gas, takes the place of a calibration curve and renders it unnecessary to refer to a curve. The constant as shown by Fig. 8 is 170,000, showing a specific heat per cu.ft. of $\frac{3.412}{170} = 0.0201$.

20 The accuracy of these meters is not affected by changes in pressure of the gas or air, since the unit of measurement is that of weight rather than of volume; that is, the meter takes cognizance of

the specific gravity, or the amount of "stuff" in a given volume of the gas. Also variation of temperature of the incoming gas does not affect the accuracy, because it is a difference of temperature, rather than a fixed temperature, upon which the measurement depends. The meter can be used for gas or air at either high or low pressure, and at either high or low temperature, provided the materials used in construction are suited to the conditions.

21 This method of measuring gas seems especially useful in connection with engines operated by gas from producers, blast furnaces, etc., and in measuring the discharge of gas or air from compressors, because the small and rapid periodic fluctuations of pressure, due to the suction of gas engines or to the discharge from compressors, do not interfere with the steady action of the thermometers. The time lag of the latter is sufficient to smooth out the curve of temperature variation, or of watts input, as the case may be, and true average results are thus indicated.

22 The temperature difference employed when operating with a constant difference, is approximately 5 deg. fahr. When a curve of temperature difference is employed, the temperature rise is from 4 to 5 deg. fahr. when the normal maximum amount of gas is flowing. This difference may be increased to 10 or 12 deg. when the rate of flow is greatly diminished, and at 100 per cent overload the temperature difference is from 2 to 2½ deg. On the autographic record one inch represents a temperature difference of one degree. The thermometers and recording device are such as to render the records accurate within 1 per cent. The minute fluctuations shown by the curves on Fig. 6 and Fig. 7 are produced by the constantly varying rate of flow in the gas mains. These can be "damped out" to any extent desired. The apparatus with which this record was taken was purposely made sensitive to minute fluctuations.

23 The electrical energy required to operate the meters is approximately 1 kw. per 50,000 cu.ft. hourly capacity. The curves shown in Fig. 7 represent variations of from 17,000 to 75,000 cu.ft. per hr., and were made with an energy input of approximately 1.15 kw. To provide for more gas and still have the record lie conveniently on the paper, it is only necessary to increase the energy input by manipulation of the rheostat hand-wheel on the switchboard.

24 The meters are so constructed that the heads can be easily removed and an air blast used for cleaning out the interior, or the entire casing, containing heater and thermometers, can be removed and dipped in gasolene for the purpose of removing tar or other deposit.

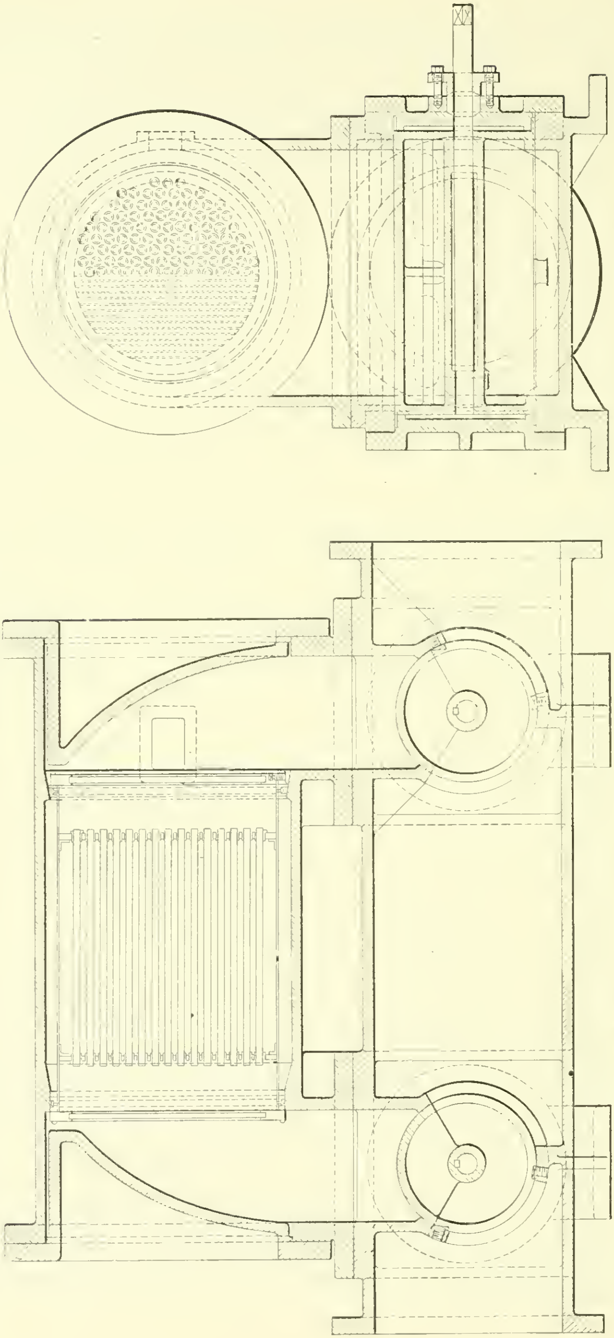

Fig. 9 Meter as Arranged for Measuring either Quantity or Quality of Steam

All parts of the meter are of rugged construction, and are of well-developed materials familiar to engineers. The heater units consist of corrugated strips of resistance ribbon about 1½ in. wide, wound spirally into discs of such diameter as to fit the inside of the wooden casing. The number of these discs depends upon the capacity of the meter. The heater shown in Fig. 4 consists of two discs.

25 The same type of meter, modified as shown in Fig. 9, can be used for the measurement of steam, and also for determining the quality or percentage of moisture of steam. When used for measuring the quantity of steam, the steam is first superheated slightly in a superheater of the ordinary type, after it leaves the boilers and before passing through the meter.

26 The heater element in the steam meter consists of tubes, as shown in Fig. 9, made of suitable resistance material and supported on insulating bushings in the tube plates, the construction being similar to that of a surface condenser. The slightly superheated steam is passed through and around these tubes, and is further heated by the electrical energy supplied to the tubes.

27 The difference of temperature produced by a given energy input forms a measure of the weight of steam flowing, just as has been described in the case of the gas meter. In cases where it is desired to make engine or turbine tests with unsuperheated steam, the steam can be reduced in temperature after passing the meter, by the injection of a spray of water. Of course the measurement of superheated steam is simpler than is the case where superheating is not a feature of the regular operation of the plant.

28 The amount of moisture carried by steam can be very accurately determined with this apparatus, by passing all of the steam through the electrical heating material and noting the amount of energy required to "fry out" the water and cause superheating to commence. The pointer over the dial of the instrument connected with the resistance thermometer in the outlet of the calorimeter indicates when the temperature of the steam begins to rise. It is proable that the only way to determine accurately the quality of wet steam is to pass all of the steam, and not a small sample, through a calorimeter. It is of course not always practicable to do this, and in such cases it is necessary to use smaller calorimeters and to sample the steam.

29 When inserted for either regular or intermittent use as a steam meter or as a calorimeter, the device can be cut off from the steam line in the manner already described for the gas meter, and as shown in Fig. 1.

30 The automatic recording device for the gas meter is so arranged that in case the flow of gas should be interrupted for any reason the current is automatically cut off at the switchboard. Also if the flow of gas becomes so small in amount that the pen reaches within a half inch of the edge of the paper, the current is cut out. When the gas has cooled the heater slightly, the current is automatically cut in again, and if the gas flow is increased the pen goes back toward the middle of the diagram and operation proceeds normally. If the gas flow continues but does not increase beyond that at which the current was cut out, the pen will "hunt" back and forth near the edge of the paper. It can be brought back toward the middle of the paper by the introduction of more energy to the meter. The gas meter is thus fully protected from possible injury due to the complete shutting off of gas supply.

31 At the other edge of the paper, representing the maximum flow of gas, the operation is similar to that already described. In order to bring the recording pen upon the range again the electrical input is increased by manipulation of the hand-wheel on the switchboard. This applies to operation by the second method described in Par. 11, in which the temperature difference between the two thermometers forms the record of gas flow. When the first method is employed, that of maintaining constant temperature difference, the meter is also automatically protected by the motor-controlled rheostat, and the range of the instrument is unlimited and it does not require manipulation by hand. It will be seen by reference to Fig. 7 that the range of the instrument when operated by the second method of varying temperature difference, is very wide, and takes care of extensive fluctuations of gas flow.

APPENDIX

DATA RELATING TO CALIBRATION CURVE, FIG. 8

Time	Wet Meter Reading	Cu. Ft. Gas Per Hr.	Average Temperature Difference Deg. Fahr.	Average Kilowatts Input	Deg. Temp. Rise Per 1000 Watts
A.M.					
10–05	90148.0				
10–10	———				
10–15	90177.5				
10–20	90192.0	17350	10.7	1.153	9.30
10–25	90206.0				
10–30	90220.5				
10–50	90396.0				
10–55	———				
11–00	90470.0				
11–05	90509.0	45200	4.25	1.150	3.69
11–10	90546.0				
11–20	90644.0				
11–25	90695.0	61200	3.25	1.160	2.80
11–30	90746.0				
11–40	90884.0				
11–45	90947.0	75600	2.70	1.160	2.32
11–50	91010.0				
P.M.					
12–05	91098.0				
12–10	91125.5				
12–15	91152.7	32640	6.25	1.22	5.12
12–20	91180.0				
12–25	91206.8				
A.M.					
9–30	91418.2				
9–35	91493.4	90240	3.90	2.05	1.90
9–40	91568.8				
9–45	91643.8				
10–00	91857.1				
10–15	92074.0				
10–30	92291.7				
10–45	92506.2	84960	4.10	2.05	2.00
11–00	92717.5				
11–15	92925.4				
11–30	93131.0				

BITUMINOUS GAS PRODUCERS

WITH SPECIAL REFERENCE TO TESTS ON THE DOUBLE ZONE TYPE

By J. R. Bibbins, New York
Member of the Society

Several manufacturers have seriously applied themselves for years to perfecting the bituminous producer. The problem has been difficult and success elusive; but the improvements of the last two or three years have been material, and likely to lead to a type universally acceptable as standard. Outside of the question of pecuniary reward, much credit is due to these manufacturers for persevering against material obstacles and personal prejudice, and at an expense ruinous to any but those possessing large resources.

2 It is the object of this paper to record the results of the most recent achievements in this direction, and to interpret them in the light of personal experience. No attempt is made to discuss the commercial aspect, and in this respect the results presented will largely be left to speak for themselves. These results are drawn from resources accurate and reliable in so far as commercial tests can be made to approximate scientific investigation. Beyond this no claims can be made for refined accuracy.

ESSENTIAL REQUIREMENTS

3 Successful operation of a modern gas engine generating station prescribes certain requirements in the producer plant:

a Continuous operation, 365 days per year. Any departure from this condition means reserve equipment, additional capital outlay and idle plant. Producer designers cannot escape at this advanced stage of the art a condition parallel to that of steam boiler practice. For this continuous service the water-seal has proved adequate, but

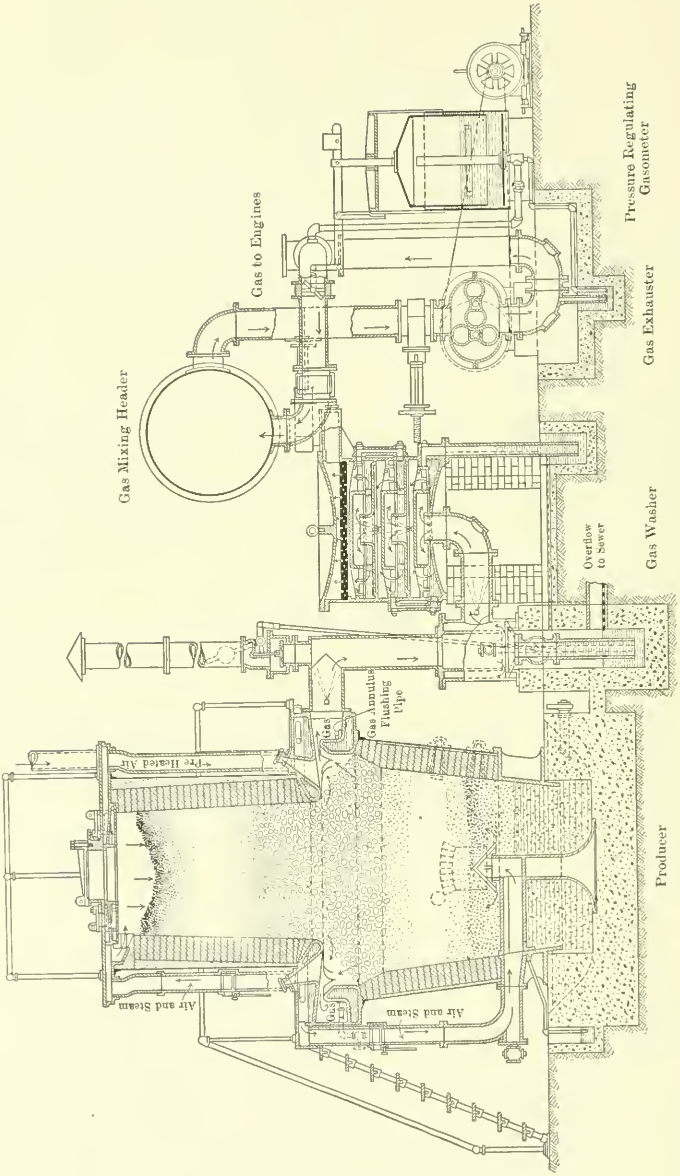

FIG. 1 SECTIONAL VIEW OF PRODUCER AND AUXILIARY APPARATUS

some means of mechanically removing ash should be developed.

b Plant suited to various kinds of fuels without remodeling, such as change of grates, etc. Fortunately gas producers are unusually flexible in this regard.

c Gas clean and free from tar. No engine design except perhaps some one of the simple valveless types can withstand the action of viscous tar deposits on the valve seats. Mechanical extraction can hardly be considered an acceptable remedy in this regard.

d Moderate labor requirements. No design will last which requires excessive attendance and large periods of shutdown for cleaning or repair.

e Prevention of clinker formations. Both labor cost and the uniformity of gas production are affected seriously by clinker. The obvious remedy is relatively low fuel bed temperatures.

f Automatic gas regulation. Large and expensive gas holders should be unnecessary. Quantity and quality regulation of gas may be made susbtantially automatic by proper design. An essential requisite is to relieve the producer attendant of all possible adjustments, as it is next to impossible to obtain at the prevailing wage the grade of intelligence otherwise necessary. The power-driven exhauster has removed a great proportion of the disabilities of the steam blown producer.

g Minimum auxiliary apparatus. It is manifestly inadvisable to nullify the high efficiency of the producer by wasteful auxiliaries. For this reason the suction principle has come into favor. Internal vaporizers provide automatic regulation quite adequate to the usual fluctuations in demand for gas, thus dispensing with the small boiler.

DESCRIPTION OF POWER PLANT, ETC.

4 The tests herein presented pertain principally to the double zone type of producer. As a complete description of this type was incorporated in the last report of the National Electric Light Association, 1909, constructional details may be dispensed with. Fig. 1

shows the arrangement in sections, comprising the following essential parts:

Water sealed ash pit,
Lower coke gasifying zone,
Central belt evaporator,
Upper coking zone for green fuel,
Air cooled top (preheating air blast),
Charging funnel open to atmosphere,
Vapor control valves for top and bottom fires,

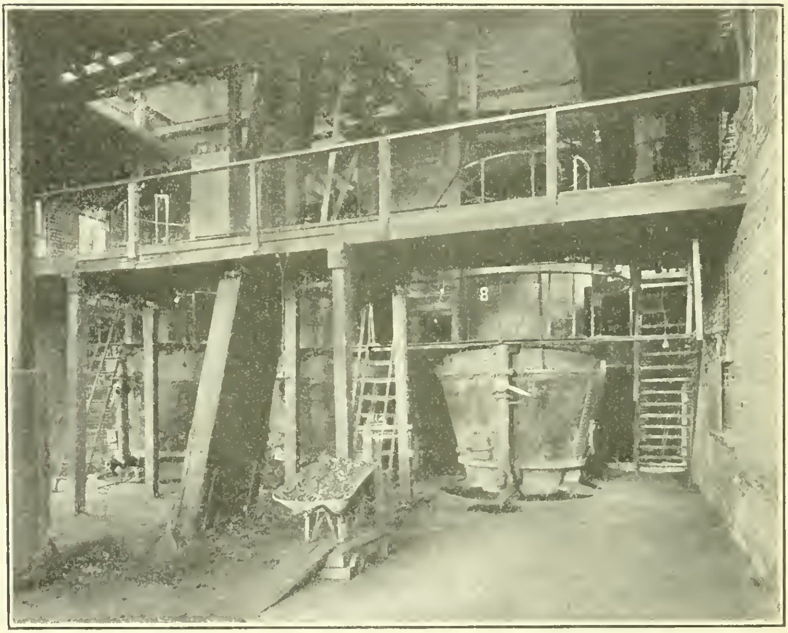

FIG. 2 525-H.P. BITUMINOUS PRODUCER PLANT, WESTERN CHEMICAL COMPANY, DENVER

Radial poke holes for raking top and bottom walls,
Static cellular washer,
Positive rotary exhauster,
Automatic by-pass regulator valve,
Regulating gasometer for maintaining constant delivery pressure to engine.

5 This system obviously works entirely by suction with the charging top at atmospheric pressure. The sole adjustment is the relative position of the vapor control valves, which are set *permanently* for any given fuel and require no change for ordinary variations in power load. These valves determine the relative rates of combustion in

the upper and lower zones, the temperatures, and the rate of settling of the two fuel beds. While the producer is not supersensitive, intelligent adjustment is necessary to secure the most uniform gas. But the gas holder is dispensed with entirely, as the production is directly proportionate to the demand, giving a constant delivery pressure at the engine.

SCHEDULE OF TESTS

6 This producer plant has been under test in commercial sizes (175 h.p.), at East Pittsburgh, since December 1907, with various fuels and under various conditions of load. Up to July 1909, a total of over 2040 hours of operating tests had been run, operating from a minimum of 47 to a maximum of 514 hours continuous tests and on both 10- and 24-hour runs. Over 266,000 lb. of coal was gasified, the fuels ranging from low grade lignites to the best Pocahontas semi-bituminous coal. Some trials were also made on meadow peat. All the gas made was tested by means of a standard three-cylinder engine of 140 h.p. operating also continuously against the resistance of a prony brake. The gas was measured by wet meters at both[1] the producer and the engine. Determinations were made regularly for calorific value by means of the Junker calorimeter; for impurities by the Sargeant filter paper method; for composition and heat value by chemical analysis. Coal was weighed on scales—not measured. Table 1 shows a complete schedule of tests; of these special tests F and G were run to determine accurately the normal standby loss; Test H to try out the type of washer shown in the sectional drawing, Fig. 1. It is apparent that this series of tests is unusually valuable in indicating results under various conditions of service. The important results follow, and are discussed *seriatim.*

DISCUSSION OF RESULTS

7 It should be noted by Table 2 that fuels containing as high as ¼ their weight of water were successfully used for power purposes. The efficiency curve (Fig. 3) fully establishes the fact that the efficiency of heat conversion is practically as high with lignites as with the cheaper fuels.

8 In the test with Texas lignite an important fact was brought out, which has especially puzzled theorists for some time, viz: That with a poor fuel the rate of combustion can be increased sufficiently to permit the same rating of the producer as with better fuel. This re-

[1]For check purposes, meter calibrated by positive holder fall.

TABLE 1 SCHEDULE OF TESTS

Test	Date.	Fuel	Duration Hours	Hr. per day	Load on Producer b.h.p.	Load on Producer Max.	Remarks
	1908						
A	4/ 2– 4	So. Am. Lignite	72	11	....	....	Purged Gas.
B	4/16–30	Col. Lignite	314	24	121.7	156.9	Continuous Test.
C	5/ 8–23	Pittsburgh	298	24	158.3	129	" "
D	7/16–31	"	370	10	158.5	206	Intermittent test.
E	8/ 4–25	"	514	10	170.8	190.7	" "
F	9/ 1–19	"	432	Standby	.....	.....	Standby test. Fires blasted 1 hr. once in 24 hr. day
G	10/12–19	"	168	"	.....	.....	
H	11/ 9–14	"	...	10	137 to	204	Washer test and capacity test
	1909						
I	6/ 1– 2	Pocahontas	46½	22½	75.6		Continuous test.
J	6/ 3– 4	"	48	24	101.4		" "
K	6/ 5– 6	"	48	24	126.5		" "
L	6/ 7– 9	"	72	24	150		" "
M	6/30– 2	Texas Lignite	72	24	128	135	" "
N	7/ 7– 8	" "	42	24	157.2		" "

moves a heavy restraint on the development of producers for the enormous lignite fields of Texas, Wyoming, Colorado, Montana and the Pacific States. In Test *N*, Table 3, a charging rate of 27.2 lb. per sq. ft. per hr. was maintained with Texas Lignites and 15 lb. with Pocahontas, both at 150 h.p. load; with Pittsburgh run of mine it was slightly higher (18.1).

9 An economy of less than 1 lb. per brake horsepower-hour is probably below previous results with bituminous producers. This

TABLE 2 TYPICAL PROXIMATE ANALYSES OF FUELS TESTED

Class of Fuel	Moisture	Volatile	Fixed carbon	Ash	Sulphur	B.t.u. per lb. as fired	B.t.u. per lb. dry
Meadow Peat—Massachusetts..........	38.10	40.54	17.86	3.50	1.05	6410	10340
Lignite—South America................	20.05	34.44	30.85	14.66		8035	10045
Lignite—Northern Colorado...........	16.63	33.78	42.22	7.37		9589	11500
Lignite—Texas........................	24.08	38.55	28.76	8.61	0.57	7974	10503
Bituminous—Pittsburgh run of mine....	2.03	34.98	56.22	6.77	1.29	13305	13590
Semi-Bituminous—Pocahontas run of mine..........................	1.39	16.01	74.28	8.32		13983	14170

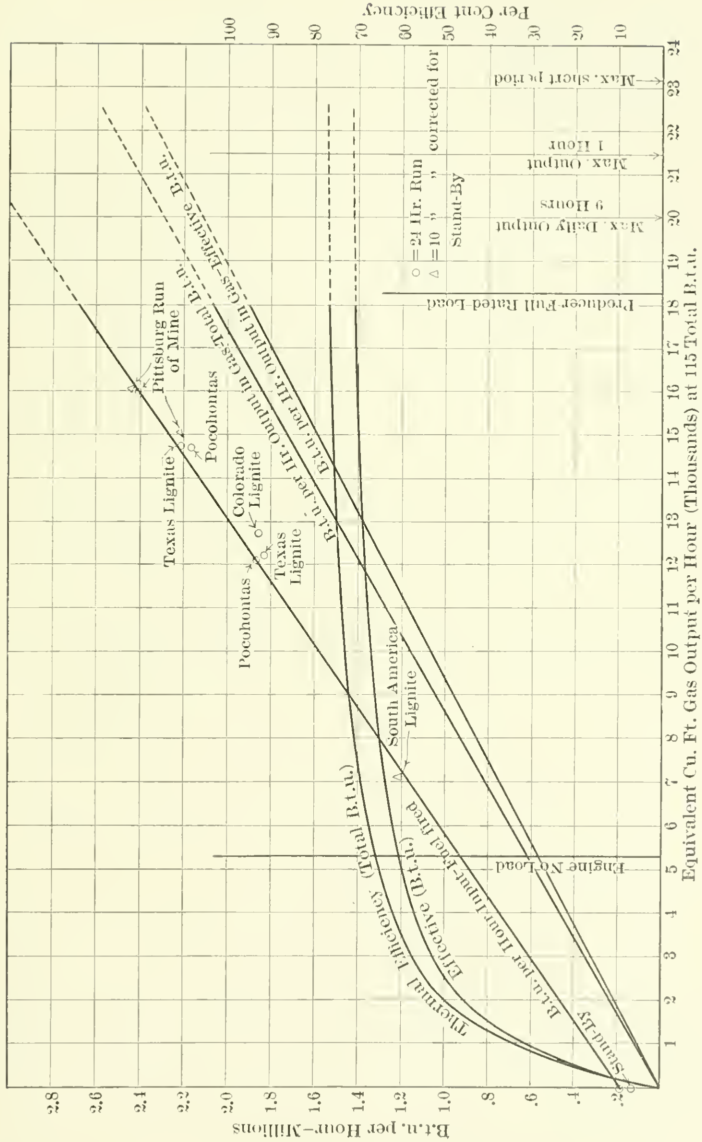

Fig. 3 Efficiency Tests, Type T-35 Bituminous Producer, Westinghouse Machine Company

corresponds to less than $1\frac{1}{2}$ lb. per kilowatt-hour in an electric generating station. An interesting point is the low standby fuel consumption, which averages in over a week's run 1 lb. per sq. ft. of fuel bed area per hour. In test G it was reduced to this amount from 1.49 lb. (Test F) simply by reducing the natural up-draught through the idle producer, by closer adjustment of the valves.

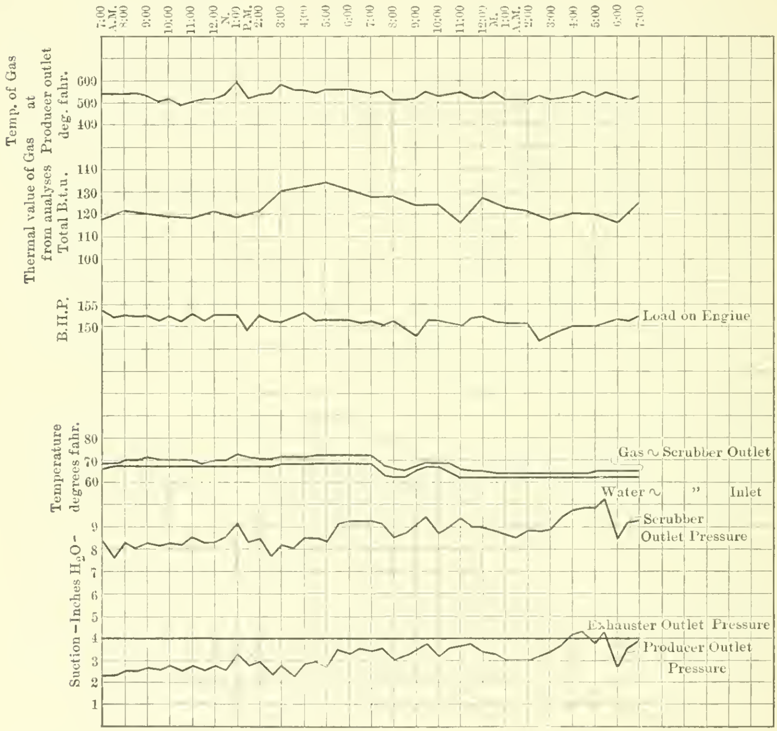

Fig. 4 Typical Log, Pocahontas Coal, Last Day of Run, $21\frac{1}{4}$ hrs.

10 Test H, which was a capacity test, shows an 18 per cent overload on gas production maintained for nine consecutive hours with Pittsburgh run-of-mine. Test C with the same coal shows nearly 30 per cent overload.

11 In heat value the gas is not high; but more important, it is fairly uniform as shown by the typical log, Fig. 4, 5 and 6. The heat value seems to bear a certain relation to the fuel bed temperature. It is found that if a certain temperature of the gas off-take is exceeded

(about 1000 deg.), vitiation of the gas ensues from excessive combustion. The condition of the fuel bed may be readily watched by means of a pyrometer (in the discharge) and with proper adjustment of vapor and draught, temperatures may readily be held below this limit; especially with lignites.

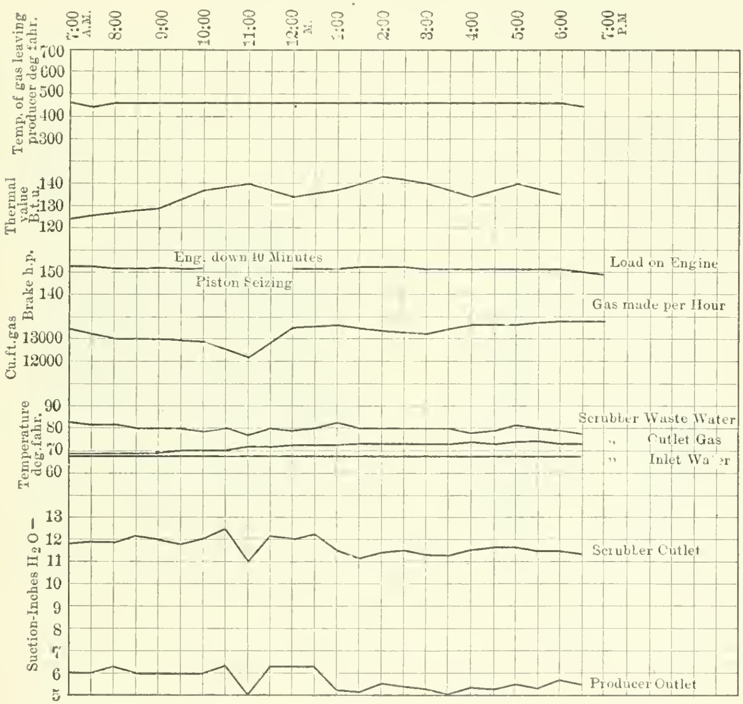

Fig. 5 Typical Log Texas Lignite, Beginning of Test

12 In this connection a comparison of these heat values with similar values from other plants is interesting, revealing the extreme range permissible with engines of modern design; see Table 10. Both are fair operating plants, but deliver gas at a considerable variation from specified value (125 B.t.u.), without occasioning any disturbance in the operation of the engine. Results from the double-zone producer show that present engine ratings are well suited to the gas, a higher compression is permissible, and that a high hydrogen content —as high as 20 per cent—does not necessarily interfere with operation.

13 Perhaps the most important result is tar-free gas. The impurities normally consist of dust and lampblack. By the filter paper method, Fig. 7, it is possible to detect the least trace of tar, which quickly discolors through to the second layer of paper. Fig. 7 shows the maximum deposit from a run on Pittsburgh coal. Note that there is no discoloration of the second paper.

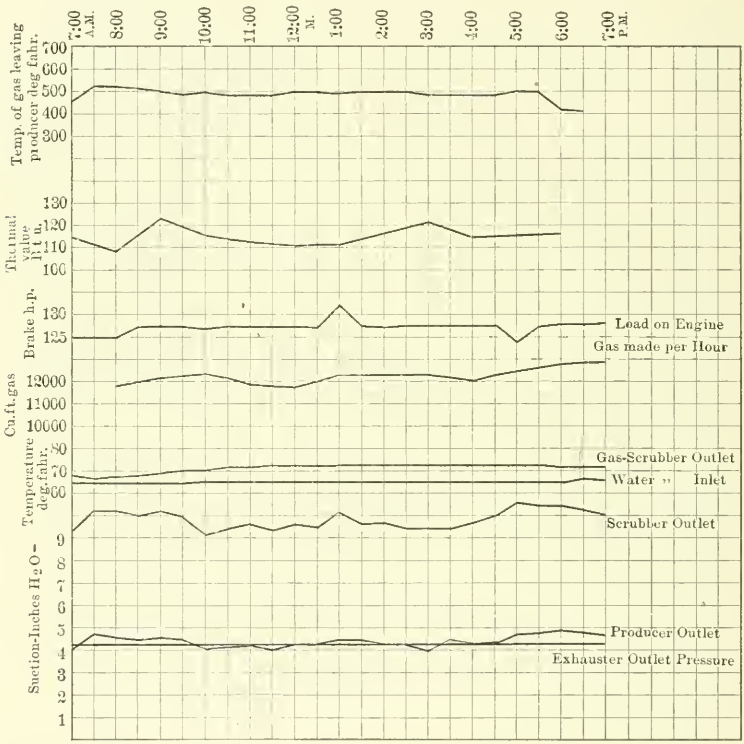

Fig. 6 Log Texas Lignite, End of Test, 114 hrs.

14 Test H, 25 determinations of Pittsburgh run-of-mine, shows well under 0.02 gr. per cu. ft., which is below the usual guarantee. In tests M and N determinations on Texas lignite averaged 0.0193 gr. per cu. ft. These results are borne out by results in the field. Seventy-three determinations at Denver[1] averaged 0.022 gr. per cu. ft. In these tests all of the gas determinations represent average gas drawn continuously throughout the day's run. In no case are

[1] Western Chemical Co

snap samples used. The latter method of testing should be rigorously avoided except for some special purposes, as it affords no indication whatever of average conditions.

15 In former papers[1] the writer has described the method of obtaining producer efficiency from isolated tests. Fig. 3 shows the close agreement of this theory with the fact based upon these several different kinds of coal tested. The interesting point is illustrated, *that the gas producer varied only 10 per cent in efficiency throughout its normal range of load.* This type will give approximately 70 per cent

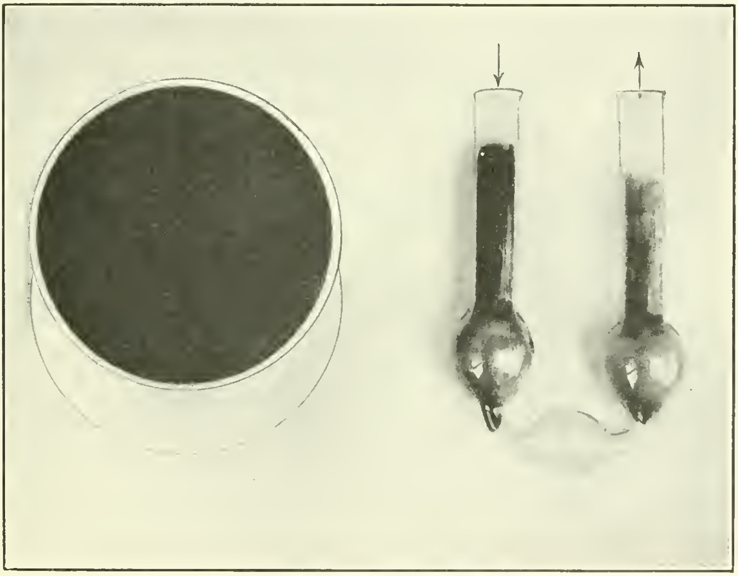

FIG. 7 COMPARATIVE METHODS OF TESTING FOR IMPURITIES

5 CU. FT. EACH 30 MIN.
0.0259 GR. PER CU. FT. FILTER PAPER, TWO LAYERS
0.0216 GR. PER CU. FT. COTTON BATTING, TWO LAYERS

efficiency (on an effective heat basis), or 77½ per cent (total heat basis), at full load. This is manifestly reasonable by inspection of Table 5. That all fuels should fall so closely on the heat input lines at various loads, is a remarkable agreement, and closer than anticipated.

16 However, in a paper by the writer[3] the same agreement was found in plotting the results of tests on another type of plant at Rich-

[1] Norton Test, Vol. 29, Transactions A.S.M.E. 1907; Transactions A.I.E.E., page 1128, vol. 27, 1908

mond, Va. The standby, and three-load determinations, followed almost on a straight line of heat input to producer.

OPERATING RESULTS

17 After the first year's period of tests, this plant was dismantled for examination. The gasification of 182,472 lb. of fuel showed no perceptible effect upon the condition of the producer, the walls being practically intact. This is due to the complete absence of clinkers and high temperatures. Experience plainly shows the latter to be the cause of clinker troubles. The fuel bed normally grades from small ash at the bottom through pure coke to green coal at the top. With proper handling, clinkers may be entirely avoided. For example, Table 9 shows a screen test of coal and ash at the Denver installation—$43\frac{1}{2}$ per cent ash through a $\frac{1}{16}$-in. screen.

18 An examination of a long gas main and the engine valves after the year's run, showed no deposits of tar either near or distant from the producer, indicating the complete fixation of the volatiles. All condensibles are removed in a static washer, the cells of which seem to automatically clear themselves of the deposit. For example the pressure drop or resistance through a month's run increased slightly more than $\frac{1}{2}$ in. The principal skill in handling this producer is required in studying the characteristics of various kinds of fuels. Each must be handled differently for best results. With friable fuels the "let well enough alone" rule is particularly desirable, as resistance of the bed may be greatly increased by too much poking.

GENERAL CONCLUSIONS

19 With the writer's good fortune to have obtained directly or to have analyzed results, from several types of producer plants, has come a conviction along certain broad lines on producer practice in general. Knowing the facts regarding daily performance from both shop and field, the statements herein contained are believed to be conservative. The idea is not meant to be conveyed that successful working has been confined to any one particular type of plant or equipment. But those undertakings that have been backed up by experience gained in tests on a commercial scale, are certainly most sure of success and worthy of support. There is much activity resembling plagiarism in the power gas field—guarantees based solely on productions from competitive results, portions of a foreign design

incorporated in an incoherent whole, etc. Such mis-matching inevitably leads to failure without thorough analysis of cause and effect. In short, the great desideratum is a campaign of investigation at the factory—not of the shiftless pounds-and-kilowatt order, but sufficiently comprehensive to facilitate accurate interpretation. Many failures that now lie to the discredit of the internal combustion system would thus have been avoided.

20 It is also patent that personal prejudice seemingly plays a far too important part in dominating the selection of plants, steam as well as gas, and its effect appears not only in the selection but also in the operation of the plant, which often makes it impossible to secure results which under proper conditions would be easily within reach. It is therefore equally as desirable to analyze reports of poor results obtained from a given plant, as of results which seem so good as to arouse suspicions of inaccuracy.

21 Finally—a present need in producer work is some reasonably accurate means of control indicating and compensating for "low gas," which may result from poor condition of fuel bed. Automatic production without the holder storage has now become an accomplished fact with the simplest apparatus, but no means are available for keeping under observation the heat value, except the cumbersome and delicate Junker calorimeters. Were it possible to alter in inverse proportion the ratio of air to gas at the engine accordingly, maximum efficiency could be maintained. But this variable factor has received practically no attention, and as a consequence producer operators are working entirely in the dark.

22 The principle of tar-free gas production has its demonstration in the type of producer under discussion, and it is believed the end justified the means, even at the slight expense of heat value. Due to unknown and complex reactions, tar laden or "green" gas possesses somewhat higher heat value than tar-free gas, due possibly to the preservation of more unstable hydrocarbons. This might then become a factor in rating, with engines designed with little or no margin. But good practice today recognizes no difference between gas of 110 and 125 B.t.u. The margin necessary is present for other reasons, and there is therefore no practical obstacle in the way of development of the tar-free type of gas producer in any form.

23 Further investigations are also urgently needed, as to the possibility of large units. If the gas engine is considered behind the times in the matter of development of large units as compared with steam practice, the producer is hopelessly so. For rapid future delvel-

opment, large units are an obvious necessity. We have steam turbine units capable of sustaining continuous loads of 30,000 h.p., boiler units of 2000 to 3000 h.p., gas producers of only a few hundred, maximum. The very multiplicity of units thereby required in the design of a large station, very seriously militates against the selection of the producer gas system of motive power.

TABLE 3 FUEL DATA

Test	Lbs. charged incl. standby	Lbs. Charged per hr.	Lbs. Charged max.	Lb. per[1] sq. ft. per hr.	Fuel Consumption Per b.h.p. hr. Gross[2]	Fuel Consumption Per b.h.p. hr. Net[3]	Fuel Consumption Per kw. hr.[4] Gross	Fuel Consumption Per kw. hr.[4] Net
A	5003	151.6	160.8	15.2	2.3	2.3	3.33	3.33
B	60740	194	228.5	19.4	1.59	....	2.31	
C	53925	181.1	207	18.1	1.14	....	1.66	
D	27157	169.2	222	16.9	1.39	1.19	2.01	1.73
E	35647	184.6	202	18.5	1.24	1.08	1.8	1.56
I	4849	104.2		10.4	1.37	....	2.0	....
J	6065	126.4		12.6	1.25	....	1.81	....
K	6403	133.4		13.3	1.06	....	1.54	....
L	10699	149.1		14.9	.983	....	1.42	....
M	16964	233.1		23.3	1.82	....	2.64	....
N	11503	272.1		27.2	1.80	....	2.61	....
F	8813	14.9			This standby rate applies to previous tests			
G	1680	10.0			Standby rate reduced by reducing updraft on fire			

[1] Based on area at level of green fuel.
[2] Including standby coal.
[3] Standby fuel deducted.
[4] Based on 92.5 per cent generator efficiency.

TABLE 4 GAS DATA

Test	Cu. ft. uncorrected	Cu. ft. per hr. 60 deg. fahr. 30 in. Hg	Max. for 1 hr.	Cu. ft. per lb. fuel	Cu. ft per b.h.p. hr.	B.t.u.* per cu. ft.† total	B.t.u. effective
A	238,900	7245	8500	47.7	102	113.4	
B	3,873,000	12400	16700	63.8	101.4	118.2	
C	4,812,200	16210	23300	89.3	102.1	113.8	
D	2,074,500	15660	21500	88.2	101.9	110.7	
E	2,797,470†	16600	17853	90.2		111	
H		17815	21511	(9 hours)		111.4	
K						119	109.7
L						120.6	112.2
M	891,300	11933		51.3	93.1	118.7	107.8
N	569,300	13092	15500	48.05	86.75	129.7	118.75

* Total heat values. H_2O determination not made during some tests.
† Corrected to 30 in. Hg and 60 deg. fahr.

TABLE 5 PRODUCER EFFICIENCY

Test	Producer Efficiency Based on		Plant Efficiency Based on	
	Total	Effective[1]	Gross Coal	Net Coal
A	76.3	....	.....	.....
B	78.8	....	16.75	.....
C	76.5	....	16.8	.....
D	77.2	....	13.9	16.05
F	75.5	....	15.45	17.6
V	.....	....	13.2	.....
J	.....	....	14.7	.....
K	.....	....	17.5	
L	.....	....	17.7	.....
M	76.8	69.8	17.5	.....
N	76.95	70.2	17.6	.....

[1] Efficiency on effective basis from 7 to 8 per cent lower than on total.

TABLE 6 DUST DETERMINATION

TEST H. PITTSBURGH RUN-OF-MINE

Load h.p.	Gas per hr. cu. ft.	Impurities in Gas, Gr. per Cu. Ft.		
		Average 5 Determinations	Max.	Min.
142	14910	0.02079	0.0432	0.0129
137	14310	0.02087	0.0398	0.0100
170	17740	0.01712	0.0318	0.0062
184	19260	0.01611	0.0287	0.0034
183	19160	0.01718	0.0459	0.0063
204	21511	....	......	......

TEST M. TEXAS LIGNITE

Duration of Tests, hr.	114
Average Load, b.h.p.	140
Lignite Fired, lb	28,467
Gas Made, cu. ft.	1,400,000
Average Impurities, gr. per cu. ft.	0.0193
Maximum, gr. per cu. ft.	0.0770
Minimum, gr. per cu. ft.	0.0010

TABLE 7 TYPICAL GAS ANALYSES

Test	Fuel	H_2	CO	CH_4	CO_2	N_2
A	So. American Lignite..............	17.4	10.4	2.4	12.4	56.6
B	Colorado Lignite..................	17.6	11.6	2.6	13.2	54.4
C	Pittsburgh........................	14.1	15.2	1.8	9.6	58.9

TABLE 8 CHARACTERISTICS OF LIGNITE GAS

WESTERN CHEMICAL CO., DENVER

Date	Heat Value (Total)				Impurities			
	No. of Determinations	Max.	Min.	Average	No. of Determination	Max.	Min.	Average
4- 8-09	3	129.6	112.4	123.0	4	0.0290	0.01567	0.0213
4- 9-09	4	121.5	113.7	118.3	.	......	......	......
4-10-09	4	123.9	106.1	113.1	.	......	......	......
4-11-09	.	.....	.....	.....	.	......	......	......
4-12-09	1	.....	.....	122.0	7	0.0617	0.0144	0.0284
4-13-09	2	115.4	111.0	113.2	6	0.0667	0.0081	0.0231
4-14-09	3	124.0	121.0	122.0	7	0.0264	0.0115	0.0184
4-15-09	2	117.3	113.7	115.5	3	0.0204	0.0051	0.0114
4-16-09	3	128.0	114.7	119.5	4	0.0198	0.0048	0.0124
4-17-09	1	.....	.....	133.3	3	0.0260	0.0209	0.0247
4-19-09	4	128.6	108.5	121.2	2	0.0194	0.0058	0.0126
4-20-09	4	128.0	108.5	117.8	3	0.0046	0.0018	0.0033
4-21-09	3	117.8	110.0	114.7	3	0.0095	0.0051	0.0051
4-22-09	3	130.0	111.0	121.0	2	0.0288	0.0113	0.02005
4-23-09	3	129.0	123.4	126.0	3	0.0048	0.0018	0.0033
4-24-09	2	126.0	106.4	115.7	3	0.0064	0.0036	0.0053
4-26-09	1	.....	.....	125.0	.	......	......	......
4-27-09	1	.....	.....	120.4	3	0.0429	0.0040	0.0179
4-28-09	3	141.6	127.0	133.2	3	0.0089	0.0026	0.0056
4-29-09	2	131.0	136.0	128.5	3	0.0099	0.0059	0.0073
4-30-09	.	.....	.....	.....	3	0.0172	0.0066	0.0123
5- 1-09	.	.....	.....	.....	3	0.0356	0.0216	0.0304
5- 2-09	.	.....	.....	.....	2	0.0587	0.0340	0.0463
5- 3-09	.	.....	.....	.....	3	0.0328	0.0067	0.0205
5- 4-09	.	.....	.....	.....	3	0.2325	0.0735	0.1381
Average				121.2				0.02227

TABLE 9 SCREEN TESTS—FUEL AND ASH—NORTHERN COLORADO LIGNITE

Western Chemical Co., Denver

	Coal	Ash
Over ¼ inch	58 per cent	23.5 per cent
Over $\frac{1}{16}$ inch	23½ per cent	33.0 per cent
Through $\frac{1}{16}$-inch	18½ per cent	43.5 per cent
	100 per cent	100 per cent

Samples represent about one bushel of material quartered down taken from stock pile.

TABLE 10 TYPICAL PRODUCER OPERATION

	Plant A Texas Lignite			Plant B Pocahontas		
	Max.	Min.	Avg.	Max.	Min.	Avg.
Date of Observation	May 20–29, '08.			Apr. 1–9, '08.		
No. of Determination	20			24		
CO_2	11.6	8.0	10.0	11.6	8.6	9.9
O_2	0.9	4.0	0.63	.....	.....	.....
CO	14.8	12.0	13.7	19.4	11.4	15.7
H_2	19.3	11.84	15.3	12.4	4.7	9.09
CH_4	2.52	1.5	1.88	8.8	5.1	67.6
N	62.4	5.7	55.2	65.1	53.9	5.93
Heat Value Total	109.9	89.2	102.7	166.4	110.4	133.1
Heat Value Effective	.....	....	.....	157.8	101.0	124.5
Fluctuation B.t.u	.....	....	20.7	.....	.....	56.0
Fluctuation Per Cent = Avg. Value	....	....	10.1	.....	.....	21.0

SYMPOSIUM ON

THE EFFECT OF SUPERHEATED STEAM ON CAST IRON AND STEEL

Three papers: Cast Iron Fittings for Superheated Steam, by Prof. Ira N. Hollis, Boston, Mass; The Effect of Superheated Steam on the Strength of Cast Iron, Gun Iron and Steel, by Prof. Edward F. Miller, Boston, Mass.; Cast Iron Valves and Fittings for Superheated Steam, by Arthur S. Mann, Schenectady, N. Y.

CAST-IRON FITTINGS FOR SUPERHEATED STEAM

By Prof. Ira N. Hollis, Boston, Mass.
Member of the Society

The failure of a number of large cast-iron fittings in use with superheated steam has rightly created a widespread suspicion of this material when exposed to high temperature. Yet on this subject there is very little information of a character to justify the wholesale substitution of steel castings for the ordinary heavy cast-iron fittings. The latter have been used with success for many years at all degrees of temperature below actual redness, and in many stations now in operation with moderate degrees of superheating (say 100 deg. fahr.) cast iron has never given the slightest trouble beyond the ordinary wear and tear.

2 The doubt as to the reliability of cast iron has seemed to spring up with its use in long pipe lines to steam turbines where the temperature has ranged from 550 deg. to 600 deg. This would lead one to ask if the difficulty has not been in the design of the piping systems rather than in the character of the material. Has not the cast iron taken the brunt of a new service and has it not suffered in the estimation of the engineering public because the conditions of that service were not fully understood?

3 A vast amount of experiment and investigation would be required for the satisfactory reply to this question, and this brief paper

is not intended as a reply, but rather to place before the Society a record of some tests that may throw light on the subject. These tests were made for the Edison Illuminating Company of Boston for the purpose of determining the bursting strength under hydraulic pressure of some large fittings which were replaced with steel castings.

4 It may be well before giving the result of the tests to inquire what is actually known about cast iron subjected to high temperature; that is, known without the possibility of controversy:

a Fittings have developed cracks and small changes of shape after a few months of actual service.

b Fittings exposed separately to superheated steam at a temperature exceeding 500 deg. fahr. have shown a permanent increase of some dimensions.

c The tensile tests of pieces cut from fittings that had failed in service indicate in some cases the possibility of permanent loss of strength.

5 The remainder of the evidence in the case may be classed as good guesswork based upon some preconceived theory as to the behavior of the constituent parts of cast iron in a rising temperature.

6 One of the curious and interesting qualities of cast iron is its permanent increase of dimensions under high temperature. This is paralleled by the permanent set of cast-iron test pieces when subject to very moderate tensile stresses. In both cases the cast iron apparently continues to grow at a decreasing rate, at least in some dimensions, when the high temperature or tensile stress is repeated.

7 How long this growth would continue is not known. Its probable limit is the flow of the material under the ultimate breaking stress. Cast iron may not be peculiar in this respect and all materials may change permanently their dimensions under moderate stress, the change growing with each imposition of the same stress. There is no doubt of this where the yield point has been exceeded. It may also be that all materials change permanently under repeated application of high temperature.

8 The cause of the persistent expansion under high temperature is still very hazy, but two possible agencies have been mentioned in a number of discussions:

a A chemical, or physical, change in the relation of the iron to the various foreign substances which fix it as cast iron.

b A molecular change due to the fact that cast iron has no well defined elastic limit or modulus of elasticity.

9 Both causes may be in operation at the same time, but the theory of chemical change has far less standing than that relating to the stresses produced by unequal expansion. While there is a temperature at which carbon changes its relation to the iron, superheated steam is probably well below that point except under very unusual conditions.

10 That cast iron loses strength when exposed to superheated steam at 600 deg. is not conclusively proved. The most that can be said is that test specimens taken out of cast-iron fittings after one year's or more exposure to a temperature of 550 deg. to 600 deg. have shown a surprising irregularity of strength in the same casting. But there is nothing to prove that new cast-iron fittings have not a great lack of homogeneity. Irregularities exist in every casting owing to the inability of the metal to flow when cooling below a certain temperature. Furthermore, the strength of a test piece cast from a given heat can rarely be taken as that of any selected part of the fitting cast from the same heat. It is common experience to find variations of strain in castings as well as variations of texture. Were any large, irregular casting cut into small test pieces, the variations of strength would probably be found to be quite as great as that reported later on in this paper. The demonstration of the loss of strength after long service with superheated steam does not seem either complete or conclusive.

11 A very brief description of the essential features of the Edison station will help to make clear what follows. The new part of the station is arranged in a series of complete units each consisting of one vertical Curtis turbine and eight boilers set in pairs. The main steam line extends along the rear ends of the boilers just beneath the brick work, four eight-inch vertical steam mains connecting each pair of boilers with the main line. Three of the vertical mains discharge through gate valves into T's, and the fourth, at the end of the line, through a gate valve into a bend.

12 The first turbine units were provided throughout with cast-iron fittings, which were ultimately replaced with steel fittings. No expansion or slip joints are used. The main steam line (something over 103 ft. long) is anchored at the turbine end and is allowed to expand freely in a longitudinal or horizontal direction carrying the lower ends of the vertical mains with it. The steam pressure is 175 pounds, the superheating generally amounts to 150 deg. fahr., although it is not constant. The actual temperature of the steam varies from 500 deg. to 580 deg., so that the main line is changing in

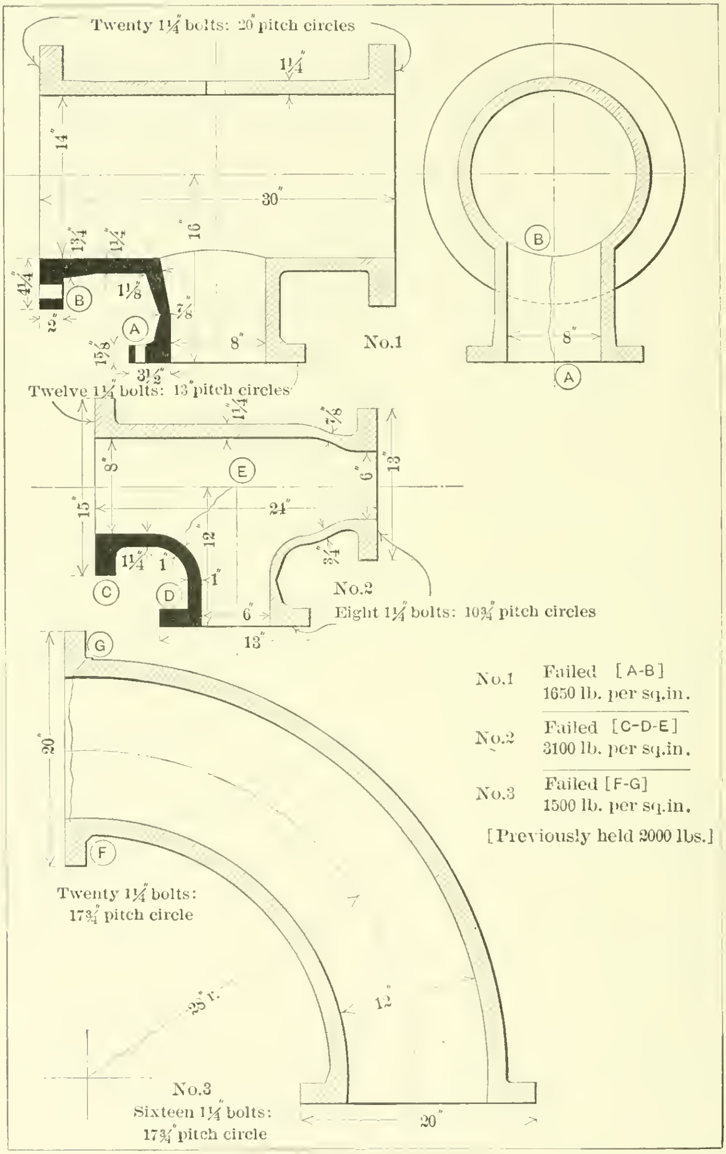

Fig. 1 Showing Points of Failure under Hydraulic Pressure of Three Cast-Iron Fittings used with Superheated Steam

length from time to time, thus moving the lower ends of the vertical mains back and forth. A series of variable stresses are consequently introduced into all parts of the pipe system, probably affecting most seriously the T's. It is this aspect of the case, namely, the effect of varying stresses upon cast iron at high temperature, that must be studied before a sound verdict can be reached.

13 The castings in the South Boston station were first suspected of failure when nearly a year after the turbine plant had been in operation one of the 8 in. by 6 in. by 6 in. T's near the boiler showed signs of deterioration, cracks appearing near the junction of the offset with the body of the T and in the flanges. Another fitting of the same dimensions and location began to fail and was taken out after fourteen months' service. Both these T's were cut up for testing and the results were so much alike that only the second is given here as that T had been exposed the longest to the strain.

14 A chemical analysis gave the following: Carbon, 3.47; Manganese, 0.10; Phosphorus, 0.366; Sulphur, 0.062; Silicon, 1.41. The tensile strength of six pieces taken from different parts of the T was found to be, 12646, 14295, 26080, 27270, 27440, 28280 lb. per sq. in. There thus appears to have been considerable variation of strength in the T unless the first two results are errors due to some faults in testing. Not considering them, the four other pieces do not appear to indicate any great falling off in service. They are as near together as would commonly be found in cast iron from the same heat. The material was supposed to be a first-rate quality of air-furnace gun iron which should have been good for 25000 to 30000 lb. per sq. in., but no tests or analyses of the heat from which this T was poured are on record.

15 Four test pieces cut from a larger T, 14 in. by 12 in. by 8 in., which had had about the same service as that from which the foregoing test pieces were cut, gave a tensile strength of 23130, 23480, 23875, 24170 lb. per sq. in. Here again there was absolutely no proof that the material had deteriorated.

16 Three test pieces were taken, for comparison, from a large manifold which had been seven years in service with saturated steam, and the tensile strength was found to be 16413, 16550, 17000 lb. per sq. in. The nature of the cast iron was not known positively, but it was bought as air-furnace gun iron.

17 It was fully recognized in the first of the foregoing tests that, while the material might not have suffered in service, nevertheless parts of the casting might have been weakened by the expansion

stresses. For the purpose of testing this, two T's were removed from the line and broken by internal hydraulic pressure, thus affording a definite idea of the strength of the castings as a whole. A third casting, an L not previously in use, was added for comparison. The three fittings are shown in Fig. 1 in which the measured dimensions and the location of the fractures are given.

18 The material was the same as that used for all the fittings of the turbine unit, air-furnace gun iron, and the chemical constituents were probably about the same. The two T's had been exposed to superheated steam of 578 deg. fahr. and less for fifteen months, or longer, and when removed had given no indications of weakness. A careful examination disclosed no appreciable distortion except in the faces of the flanges which were no longer plane surfaces. There were several high spots that could not have existed when the flanges were faced off.

19 No. 1 was a 14-inch T with an 8-inch offset. The openings were closed by heavy cast-iron plates fitted to the flanges and bolted. The pressure was produced by a steam-driven outside-packed plunger pump, and was measured by means of a small conical safety valve, one-tenth of a square inch in area, and directly loaded by dead weight applied as the pressure increased. The indications of the small valve were constantly compared with a hydraulic gauge previously tested and calibrated at the Crosby manufactory. The fitting broke as shown at an internal pressure of 1650 lb. per sq. in. The plates covering the openings did not reinforce the T to any great extent as the bolts were smaller than the holes and the joints around the flanges were leaking appreciably when the fracture occurred.

20 No. 2 fitting was an 8-in. by 6-in. T. It was broken in precisely the same manner as No. 1 and gave way at an internal pressure of 3100 lb. per sq. in.

21 No. 3 fitting was a 12-inch L. Its two openings were closed with cast-iron plates and it was burst in the same way as the others. The joints practically gave out at a pressure of 2000 lb. per sq. in. although the pressure was kept on for some minutes. For the second attempt to run the pressure up, the bolts were set up with a very heavy wrench, which undoubtedly put a bending moment on the flange. The fitting finally parted all around the root of the flange at a pressure of 1500 lb. per sq. in.

22 Four test pieces were cut from the larger T and broken under tensile stress. Their dimensions were almost exactly $\frac{3}{4}$ in. in diameter by 6 in. between fillets. Two of them were broken cold and

gave a tensile strength of 22150 lb. per sq. in., and two were broken at a temperature of 590 deg. at 20050 lb. per sq. in. The temperature of the latter was maintained by means of a cylinder-oil bath, the oil being placed in a large tube surrounding the test piece and kept hot by a gas flame.

23 No information could be obtained as to the original strength and chemical composition of the iron and it would be impossible to prove that it had changed either in strength or in composition. There is ground, however, for believing that it had changed, as the smaller T mentioned gave as high as 28000 lb. tensile strength in one specimen.

24 A comparison of the larger T with those tested and reported in the Valve World for November, 1907, throws an interesting light on the subject. The formula there published as derived from a very large number of tests of cast-iron and ferro-steel fittings may be taken as a basis for calculating what should have been the bursting pressure of the 14-inch T. This formula is $B = \frac{T}{D} \times S$, where

D = inside diameter of the T

T = thickness

S = tensile strength of the material multiplied by 60 per cent

B = bursting pressure in pounds per square inch.

25 Taking the tensile strength of the cast iron when hot at 20000 lb. per sq. in. the diameter of the T at 14 in. and the thickness at $1\frac{1}{4}$ in. the value of B is 1070 lb. per sq. in. whereas the T actually burst at 1650 lb. This did not seem to indicate weakness or deterioration.

26 It is interesting to inquire here what stress existed in the T during its service. That due to the steam pressure was small when compared with the actual bursting pressure, but that due to expansion may have been serious in its effect. The first T in the main steam line was located at 4 ft. $8\frac{5}{8}$ in. from the anchorage, the second 37 ft. $8\frac{5}{8}$ in., the third 70 ft. $8\frac{5}{8}$ in., and there was no expansion joint to ease off the pressure on the vertical mains. Taking the third T for purposes of illustration, certain suppositions can safely be made:

a The lower flange of the vertical pipe moves in a horizontal plane as the main pipe expands and therefore the lowest point of the axis of the pipe moves parallel to itself.

b The upper end of the vertical pipe is practically fixed. The expansion of the main steam pipe thus puts an S bend in the vertical pipes and introduces large bending movements

into both ends of it and into the T. The actual length of the pipe between its lowest flange and the upper end is 26 ft., but the length between the upper surface of the T and the upper end of the pipe is about 28 ft.

27 The linear expansion of the main steam line is about 3 in. when heated to 578 deg. fahr. The effect of this is supposed to be halved by cutting the pipe short and springing the flanges into place when making the joints. There is thus an initial deflection in the vertical pipe. This is overcome as the pipe is heated and carried as much farther on the other side.

28 The value of the deflection in the lower end of the pipe is then taken at 1.5 in. The formula for the maximum deflection of a beam fixed at one end and moved parallel to itself at the other end is

$$Y = \frac{Wl^3}{12\,EI}$$

W = load in pounds or push of the horizontal pipe.
l = length in inches.
E = modulus of elasticity.
I = moment of inertia of the pipe.

The inside diameter of the pipe is 8 in. and its thickness is 0.322 in. giving the value of $I = 72.5$. E is taken at 30,000,000.

29 The equation for the deflection is then

$$1.5 = \frac{312^3\,W}{12.725 \times 30{,}000{,}000}$$

and W is found to be 1288 lb. Thus if the expansion of the pipe is exactly split by cutting the main line short, the push on the lower end of the vertical mains is 1288 lb. The point of contrary flexure in the S bend of the pipe is about 179 in. above the junction of the offset of the T with its main body. The bending moment in the offset of the T is therefore 1288 × 179 inch-pounds and the stress set up is

$$S = \frac{Mc}{I} = \frac{1288 \times 179 \times 5}{290} = 3975 \text{ lb.}$$

30 While this calculation is not entirely reliable on account of the uncertainty as to the elastic curve of the vertical pipe, nevertheless it is a fair indication of the stress to be expected in this T when the

temperature of the pipe reaches 578 deg. Furthermore, it is made under the supposition that the expansion of the pipe was lessened by an initial pull and that all the joints came exactly fair before setting up the bolts. It is easy to imagine how serious the stresses might have become under actual conditions of inaccurate fitting. The one element of splitting the expansion is very uncertain. The foregoing stress might easily have been doubled, resulting in pulling the T quite out of shape and in setting up internal strains certain to weaken the material in places.

31 Under such conditions, it was, and would generally be, wise to replace the cast-iron T's with cast steel which would yield more readily to expansion and which would be safer at much higher tensile stresses. The reason for the substitution ought not to be lost sight of in such a case, if cast iron is to be judged fairly. It is made because it is cheaper on the whole to replace the cast iron with steel rather than to put in expansion or slip joints. Perhaps the steel casting is also much easier to take care of than any form of expansion joint. The unreliability of cast iron in such a service has nothing to do with the case: it is merely that the design usually adopted for steam piping does not quite fit cast iron.

THE EFFECT OF SUPERHEATED STEAM ON THE STRENGTH OF CAST IRON, GUN IRON AND STEEL

By Edward F. Miller, Boston, Mass.
Member of the Society

The object of this paper is to describe some experiments made to determine the effect of superheated steam on cast iron, gun iron and steel. From each piece to be tested two tension specimens were made, one to be subjected to the action of superheated steam, and one to be used in obtaining the original strength of the piece.

2 All of the specimens were made with screwed ends in accordance with the specification prepared by the American Society for Testing Materials. The tension tests were made on a 100,000-lb. Olsen testing machine, the specimens being screwed into spherical holders attached to the heads of the testing machine, thus ensuring a straight tension pull without any bending.

3 The specimens to be subjected to superheat were placed on a wire grating suspended at the center of a 12-in. iron pipe about 3 ft. long, supported horizontally on brackets. The ends were closed by blank flanges. Steam was supplied by a small pipe, a flow at low velocity being maintained at all times. The under side of the pipe was heated by Bunsen gas burners. Thermometers, in wells reaching down to the grating on which the specimens were placed, gave the temperature of the steam, the pressure being read from a steam gage on the supply pipe.

4 For the tests plotted in Fig. 1, the average gage pressure in the superheating pipe was 93 lb. and the average temperature 660 deg. fahr. The gas flame was extinguished at 5 p.m. and lighted again at 7 a.m. The temperature reached 660 deg. fahr. by 11 a.m. and by 5 p.m. would be as high as 700 or 720 deg. fahr. Steam was kept in the superheater during the night. The total time these specimens were exposed to superheated steam was 260 hours, and the exposure to saturated steam was 460 hours. A chemical analysis of the iron tested is given in Table 1.

TABLE 1 CHEMICAL ANALYSIS OF CAST-IRON SPECIMENS, FIG. 1

	Phosphorus	Total Carbon	Graphitic carbon	Manganese	Silicon	Sulphur
Cast Iron Gibby Foundry........		3.51	3.02	0.37	1.88	0.05
Gun Iron Hunt Spiller................	0.41	3.25	2.60	0.24	0.54	0.09
Cast Iron Broadway Foundry...........		3.34	2.84	0.38	2.26	0.09

5 For the tests plotted in Fig. 2 the average gage pressure was 82 lb. and the average amount of superheat about 390 deg. fahr. These specimens were subjected to superheated steam for 520 hours, and

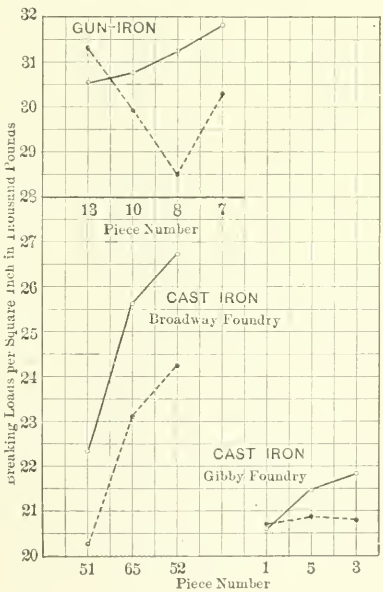

FIG. 1 BREAKING LOADS OF GUN-IRON AND CAST-IRON TEST PIECES SUBJECTED TO ACTION OF SUPERHEATED STEAM

to saturated steam for 920 hours. A chemical analysis of three of the semi-steel specimens is given in Table 2. This semi-steel was made by adding 200 lb. of steel to 1500 lb. of cast iron. The analysis of the gun-iron showed, total carbon, 3.37; graphite, 2.44; manganese, 0.34; sulphur, 0.11; silicon, 1.65.

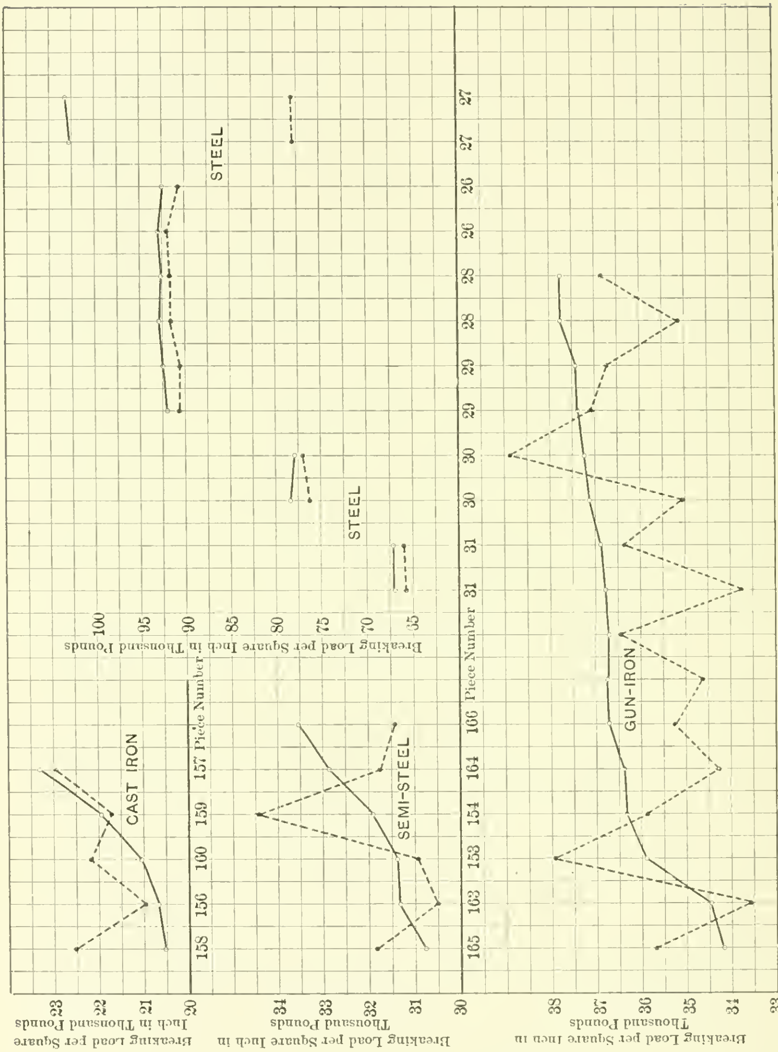

Fig. 2 Breaking Loads of Gun-iron, Semi-steel and Cast-iron Test Pieces Subjected to Action of Superheated Steam

6 The composition of two of the rolled-steel pieces No. 26 and No. 27 was as follows:

	Phosphorous	Total Carbon	Manganese	Sulphur	Silicon
No. 26	0.85	....	0.73	0.026	0.026
No. 27	0.116	....	0.90	0.057	0.031

7 In Fig. 1 and Fig. 2 the open circles represent the ultimate strength per sq. in. of the original specimen while a full circle on the same ordinate gives the strength per sq. in. of the comparison specimen which had been subjected to the action of superheated steam. By figuring the per cent loss in strength in each specimen and then

TABLE 2 CHEMICAL ANALYSIS OF SEMI-STEEL SPECIMENS, FIG. 2

Phosphorus	Total Carbon	Graphite	Manganese	Sulphur	Silicon
.....	....	2.64	....	0.11	....
0.24	3.48	2.39	0.35	0.11	1.91
0.61	3.22	2.83	0.44	0.49	2.62

taking the average of these per cents it appears that the cast iron from the Broadway Foundry (Fig. 1) lost 9.5 per cent; that of the Gibby Foundry 2.4 per cent. The cast iron of Fig. 2 came from the Waltham Foundry; here there is apparently a gain in strength of 1.8 per cent. Fig. 1 and Fig. 2 show that gun-iron loses strength, Fig. 1 showing a loss of about 3.5 per cent, and Fig. 2 about 2.1 per cent.

8 The tests on semi-steel show an average reduction of strength due to exposure to the steam, of about 0.4 per cent, four out of six pieces showing quite a reduction. If piece No. 154 is not considered, the percentage reduction of strength would be much greater.

9 Four grades of steel were tested; two pieces from a bar of 65,000 to 70,000-lb. tensile strength, two from a bar of 75,000 to 80,000-lb. tensile strength, two each from three bars of about 90,000-lb. tensile strength, and two from a bar of over 100,000-lb. tensile strength. The 65,000 to 70,000-lb. steel showed a loss of 1.8 per cent due to exposure to the steam, the 75,000 to 80,000-lb. steel a loss of 1.9 per cent, the 90,000-lb. steel a loss of 1.5 per cent, and the 100,000-lb. a loss of 24 per cent.

10 While one is not justified in drawing many conclusions from the results of as few tests as are quoted here, still it is evident from Fig. 1 and Fig. 2 that the metals tested have suffered a loss in strength due to their exposure to the steam. A paper bearing on this subject,

Materials for the Control of Superheated Steam, by M. W. Kellogg, appeared in the 1907 Transactions of the Society. In the Valve World, March 1908, are given the results of tests on cast iron taken from the body of a 14-in. valve which had been in use for four years on a main carrying steam at 200 lb. pressure and superheated to a temperature of 590 deg. fahr. A number of test bars cut from the body of the valve showed a loss of strength of 41 per cent when compared with the strength of the original metal as determined from coupons tested at the time the valve was made.

11 Fig. 1 in this paper formed part of the thesis of H. A. Terrill, M. I. T. '07, and Fig. 2 part of the thesis of F. M. Heidelberg, M. I. T. '09.

CAST-IRON VALVES AND FITTINGS FOR SUPERHEATED STEAM

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Member of the Society

There have been many failures of cast-iron valves and fittings in piping systems carrying steam of high pressure and high superheat. The ordinary extra-heavy flanged cast-iron fittings which are listed in many manufacturers' catalogues as suitable for 200 lb. pressure and which have to meet a close price competition, have successfully carried a pressure perhaps as high as 150 lb. or more. No doubt the fittings and valves can support a steady pressure of 200 lb. without bursting, but there have been many failures when carrying superheated steam of lower pressure.

2 These fittings are not too well suited for permanent work of even 150 lb. pressure, and many engineers in control of such matters in stations of a representative type prefer to design their own parts rather than to trust the usual run of commercial extra-heavy fittings.

3 Probably on account of the advertised ability to support a high steady pressure these extra-heavy fittings and valves have been used in a number of instances for superheated work. After a short time, six months or even less perhaps, cracks make their appearance; valves leak, seats become loose, castings grow in length and surface cracks become so large in size and in number that the casting is removed from the line.

4 A few repetitions of this experience seem to justify the conclusion that cast iron is not fit material for high-temperature steam. The natural substitute is steel, which is used with fair, even complete, success in many cases.

5 It is known that cast iron will grow with repeated heatings and coolings, often observed in the ordinary straight grate bar. When the bar is first heated it expands and cools as it contracts; but if the temperature has been high, the bar will increase in length. With a second heating, a further increase takes place, followed by many others. As a consequence the long single, straight, flat grate

All papers are subject to revision.

warps and proves the wisdom of McClave's rule "Keep your long lines of metal away from the fire."

6 This subject of growth has been treated very completely by Outerbridge in his excellent paper published in the Journal of the Franklin Institute for February 1904. Mr. Outerbridge heated his samples to redness or above, temperatures greatly exceeding that to which a steam-pipe fitting is subjected.

7 A rough experiment on this line was tried by the writer with two samples, one of an ordinary cast iron and a second of a high-grade cast iron, which has proved itself capable of carrying superheated steam and of which a detailed analysis is given in the following pages of this paper. The two samples were each six inches long and one inch in diameter. They were placed in a banked fire over night, reaching a dull red heat, and were allowed to cool in the air. A slight growth as measured by micrometer was found in each piece.

8 This treatment was followed for two or three nights and the growths were measured. There was an increase in the length of each of the samples, the high-grade iron having increased in length slightly more than did the ordinary iron. The experiment so far as it went tended to show that the growth of cast iron does not necessarily unfit it for the usual degree of superheat in power-house work.

9 Many grades of brass will crumble when heated in a forge to a barely visible red, and are quite unfitted to support any stress at such a temperature. But this characteristic in no way unfits very ordinary cast brass for saturated steam work, and one should not hesitate to use a valve of cast brass up to three inches in diameter for 150 lb. saturated steam pressure. Three inches is not usually exceeded because values of large brass bodies are expensive.

10 Articles have appeared in various publications showing the disability of cast iron, tensile tests being made before and after the use of fittings of ordinary iron. Cases of bronze seats dropping from valves were cited and it was not difficult to prove that something better than ordinary cast iron was needed for steam of 180 lb. pressure and 250 deg. superheat. These failures came from two causes. In the first place the iron itself was not of sufficiently good quality; and, secondly, the parts were not thick enough. The static stress probably did not exceed 1000 lb. in the body: but static stress is not the important load which fittings have to support.

11 Stresses from expansion and contraction within and without the casting and stresses from pulling up joints no doubt greatly exceed the static load even in pipe very carefully erected. The troubles are

aggravated by the action of the steam itself, but it is yet to be proved that the steam or its high temperature will of itself start cracks in a properly designed fitting.

12 The ordinary commercial extra-heavy flanged tee, 8 in. inside diameter, has a body $\frac{7}{8}$ in. and flanges $1\frac{5}{8}$ in. thick. It is made of common iron, having a tensile strength of about 18000 lb. Such a fitting will fail with superheated steam at 175 lb. pressure and 200 deg. superheat. Within a year the inner surfaces will have a network of cracks, some of which will increase in depth till they extend through the body. The flanges will crack outward from the bolt holes and the fitting will become not only leaky but dangerous as well. The writer has observed just such castings, an analysis of some of them being given later in this paper. Similar effects have been experienced by a great many steam users. The fittings are inherently weak to begin with, so that the failures do not prove that a heavier fitting of better iron is unsuited for superheated steam work.

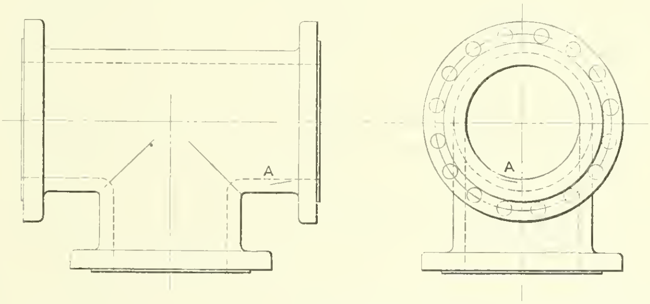


FIG. 1 A 10-IN. STEEL FITTING, THE IRREGULAR LINE AT *A* SHOWING POINT OF FAILURE UNDER SUPERHEATED STEAM SERVICE

13 Within the experience of the writer steel fittings have failed with superheated steam. Out of twenty-five steel gate valves, 6, 8 and 10 in. in diameter, not more than four were fairly tight after one year's service, the bodies themselves yielding enough to leak badly. Some defects in the castings developed allowing steam to pass straight through the walls, when they left the foundry. Some of these defects were such that the fittings and valves could not be repaired. In some cases seats were scraped in once or twice and holes were plugged up or patched, but the material would not have been satisfactory without this working over. Yet all these castings were heavy, materially thicker than the commercially extra-heavy cast-iron product, and had passed a rigid inspection.

14 Fig. 1 shows a 10-in. steel fitting; the irregular line at A showing a defect developed after use. The line does not pass clear through the casting, and no doubt the piece was amply strong to resist rupture even after the fault developed. Some of these fissures went 3 in. back and were 5 in. broad. Such a large opening in a shell is objectionable for there are blow-holes enough adjacent to it to pass steam in large quantities. Some fittings of this kind were removed from the line entirely, while others were plugged or patched.

15 No doubt a thoroughly sound steel casting is able to withstand highly superheated steam. There are several connected to the system under discussion. So far as it has been possible to observe, superheated steam does not of itself initiate defects and it is not supposed that the sound metal undergoes a change, either chemically or structurally. But if there is an initial defect, superheated steam is much more active in bringing out the objectionable features of that defect. It may well be that the material within the body, and not a part of the actual metal, suffers through change of some sort. This material does not add to the strength of a casting but it may serve to stop up holes if allowed to lie undisturbed.

16 It would appear that some material better than the ordinary steel casting was desirable for high temperature work. Such a material is found in gun iron. Gun iron is nothing more than a high-grade cast iron, which any first-class iron foundry can produce. In the days of the smooth bore cannon, a few foundries discovered that it was possible to produce an iron having a tensile strength of 30,000 lb. or more. The government specified it for its guns and it was called gun iron. Probably a tensile strength of 30,000 lb. is not needed in steam fittings, but iron of that quality is well adapted for 180 lb. steam with 300 deg. superheat.

17 From such observations as have been thus far possible it appears that certain elements in the iron are liable to cause trouble when present in excess, and perhaps the worst of these is silicon. It is at present going too far to say that every high silicon iron will fail and that every low silicon iron will prove successful, but there is much evidence pointing toward the correctness of such a surmise. In any event iron of low silicon, low phosphorus and low carbon—in other words, gun iron—has proved successful.

18 The following analysis shows the character of a casting which failed at 250 deg. superheat:

Silicon	2.40 per cent	Manganese	0.52 per cent
Sulphur	0.067 per cent	Total carbon	3.19 per cent
Phosphorus	0.94 per cent	Combined carbon	0.25 per cent

19 A second failure developed in this iron:

Silicon	1.98	per cent	Manganese	0.42	per cent
Sulphur	0.068	per cent	Total carbon	3.31	per cent
Phosphorus	0.65	per cent	Combined carbon	0.24	per cent

20 In each of these cases a sample was taken by drilling a hole straight into the body after the part had been in service a year or more and was in bad condition.

21 The following analysis is of an iron that has been successful in every respect for four years under 300 deg. superheat:

Silicon	1.72	per cent	Manganese	0.48	per cent
Sulphur	0.085	per cent	Total carbon	2.45	per cent
Phosphorus	0.89	per cent	Combined carbon	0.17	per cent

22 The latter sample is from an 8 in. valve and it is tight today, no repairs whatever having been made upon the valve during the four years though the bonnet was taken off once to permit internal examination. The outer surface of the valve was covered with 85 per cent magnesia insulation, four and one-half inches thick. The inner surface appeared sound; a microscope revealed no cracks or other defects. The unfinished surfaces were struck several sharp blows with a ball-peen hammer, a hand chisel was driven straight at the surface and some thick chips were cut off from the rough portion. If the metal had suffered to such an extent as cast iron is supposed to suffer, some of the defects would have made themselves manifest. After these treatments the valve was reassembled and has continued to perform its work properly.

23 Foundrymen are not afraid to attempt to produce this iron. No difficulty whatever was encountered in securing bids for valves made of the following mixture:

Silicon	1.40 per cent to 1.60 per cent
Phosphorus	0.20 per cent to 0.40 per cent
Sulphur	0.06 per cent to 0.09 per cent
Manganese	0.45 per cent to 0.75 per cent
Total carbon	3.00 to 3.25 per cent

It will be noted that the percentages of silicon and phosphorous are low.

24 There is of course a decided advantage in depending upon chemical analysis for determining the suitability of fittings. A hole can be drilled at any time in the actual fitting and a few grams of

sample secured. Very few of us are willing to destroy a fitting to obtain a test bar, and test coupons cast in the foundry may or may not represent the actual piece.

25 Superheated steam was in commercial use in Europe before the practice had gained its present hold here. England and Germany were using superheated steam twenty or more years ago. The writer has not discussed this subject with engineers from abroad, but wishes to quote briefly those who have.

26 E. D. Dickenson, of Schenectady, on a recent trip abroad asked a great many manufacturers whether they used steel for their superheated work and received a negative reply in each instance. When the manufacturer was questioned in regard to his iron mixture he shrugged his shoulders and replied that he made his iron fit his needs, be it gas-engine cylinder or steam pipe.

27 John Primrose, in Power and the Engineer, for June 8, 1909, states that he discussed the matter with English and German engineers. In one instance a well-known German engineer, who had used superheat for twenty-five years, was surprised that he had not learned of the effect of superheated steam upon cast iron. The engineer promised to investigate the matter in Germany, but he could find nothing to bear out the contention, and could find no one who believed that such a thing was possible.

28 It is not the author's intention to state that steel of good quality will not do for superheated work. Some manufacturers are putting out fittings of open-hearth steel which are doubtless good; but any foundry can make gun iron if it will, and delay and uncertainty will be decreased by its use.

GAS POWER SECTION

REPORT OF PLANT OPERATIONS COMMITTEE

Your Committee has devoted all possible time during the year to executing the instructions of the Gas Power Section and begs to present this report.

2 Briefly, the duties of the Committee, as outlined by the secretary of the Gas Power Section, were to prepare a standard set of forms to be used in connection with the operation of gas power plants, which would show:

- *a* The load curve for various times of the year.
- *b* Cost, character and amount of material used in operating.
- *c* Repair material, cost, etc.
- *d* Operating labor as to the number and character of men, wages, etc.
- *e* Repair labor, cost, etc.
- *f* Detail dimensions of the plant.
- *g* Data on reliability of operation.

3 Taking the requirements of the first six items collectively, as item *g* does not require a special form, your Committee has prepared a set of six forms which are submitted for your approval, as follows :

- Form 1 is a Producer Log, for a daily report of the operation of the producer plant.
- Form 2 is an Engine Log, for a daily report of the operation of the engine plant.
- Form 3 is a Load Curve Form for plotting the load on the station for any desired day.
- Form 4 is a Monthly Data Sheet. It is intended for the collection of data obtainable from the daily station records, pay rolls, etc., so as to present a comprehensive monthly statement of the operation of the plant.
- Form 5 is a Monthly Cost Sheet. It is intended to show, in a few items, the station costs both of operation and of repairs.
- Form 6 is a Dimension Sheet which is self explanatory.

4 All the forms, with the exception of the Monthly Data Sheet, are of the same size as the standard business correspondence sheet, namely, 8½ in. by 11 in.; therefore they may be readily filed in any commercial form of vertical filing cabinet. The requirements of the Monthly Data Sheet are obviously beyond the scope of the standard 8½ in. by 11 in. size. It is therefore made on a sheet just double this size, namely 11 in. by 17 in., so that one fold through the middle of the long way of the sheet reduces it to the standard 8½ in. by 11 in. size, and it may be filed in the same size cabinet. These sizes permit any company having standard letter files to conveniently file, keep and refer to the various forms.

5 Taking up these forms in detail, the Producer Log and Engine Log as submitted provide for a station of not more than three units. This seems to cover the majority of the gas power plants today. Should any company having more than three units desire to use these forms it would be a simple matter to have them reproduced on the 11 in. by 17 in. paper and thereby obtain space for any probable number of units. The Monthly Data Sheet as submitted is also based on a maximum of three units, and here again it would be a very simple matter to provide for additional units by a slight change in the spacing at the top of the sheet.

PRODUCER LOG

6 The Producer Log is intended to be kept by the operator in charge of the producer room. At the left hand side of the sheet is to be recorded the time of starting and stopping each unit and the length of its run, by drawing a vertical line from the time of starting to the time of stopping. The red[1] horizontal lines indicate the time; the longest ones, the hours, the shortest ones, the half-hours, and the others, the quarter-hours. When a producer goes into service, the operator should make a record on the nearest 15-min. line, either by a dot or by a short horizontal line. If the producer is taken out of service again during that day, the same means should be employed to indicate the time. These two dots or short horizontal marks are then to be connected by a vertical line, the length of the vertical line indicating the time the producer is in service. If it should be in service at the beginning of the day and run through into the next, a vertical

[1] Black ink only used in these reproductions. Captions explain colors used in original forms

FORM 1 10-27-'09

THE __________________________________ COMPANY

(City) (State)

Station No.________

GAS POWER PLANT

PRODUCER LOG

Date ________ 19___

	In Service Producer			Pounds of Fuel Fired Producer			Resistances Inches of Water						Temp. Gas Leaving Prod. Deg. Fahr.		
	NO. 1	NO. 2	NO. 3	NO. 1	NO. 2	NO. 3	NO. 1		NO. 2		NO. 3		NO. 1	NO. 2	NO. 3
							P.	S.	P.	S.	P.	S.			
P. M. 12															
A.M. 1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12 P.M															
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															

WATER METER
(Readings in cu. ft.)

This reading ________
Last reading ________
Difference ________

GAS MADE

__________ cu. ft.

GAS VALUE (GROSS)

__________ B. t. u.

FUEL VALUE

__________ B. t. u.

Remarks:

____
Chief Engineer

See other side

FORM 1, PRODUCER LOG. REPRODUCED QUARTER SIZE ($\frac{1}{2}$ WIDTH AND HEIGHT)

THE ACTUAL FORM IS TO BE ON A STANDARD LETTER-SIZE SHEET $8\frac{1}{2}$ BY 11 IN. HORIZONTAL LINES UNDER THE HEADING AND TO THE RIGHT OF THE RECORD OF PRODUCERS IN SERVICE TO BE RULED IN BLUE; OTHER LINES IN RED.

(SEE NEXT PAGE)

(The following note is to be printed on the back of Form 1 of which it forms a part.)

Note: The time in service is to be indicated by a vertical line having its upper end at the time when the producer was started and its lower end at the time when the producer was stopped. The longest horizontal lines indicate the hours and the other lines indicate the quarter-hours. The water-meter should be read at the same time each day.

The gas value given is to be the gross value.
P is abbreviation used for producer.
S is abbreviation used for scrubber.

This log is to be made up at the Station and signed by the Chief Engineer. It must reach the Office not later than noon of the day succeeding that for which the records are made.

FORM 2 10-27-'09

THE ______________ COMPANY

(City) (State)

Station No. ____

GAS POWER PLANT

ENGINE LOG

Date ________ 19__

	In Service Engine			Indicating Wattmeters			Temperatures, Deg. Fahr.		
							Water		Gas at Throt.
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	In	Out	
P.M. 12									
A.M. 1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12 P.M.									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Water Meter
This reading ____________ cu. ft.
Last reading ____________ cu. ft.
Difference ____________ cu. ft.

Supplies
Cylinder oil ____________ gal.
Engine oil ____________ gal.
Other lubricants ____________
Waste ____________ lb.
Other supplies ____________

Remarks: ____________

Integrating Wattmeters

	No. 1	No. 2	No. 3	Auxil.
This reading				
Last reading				
Difference				

____________ Chief Engineer

See other side

Form 2, Engine Log. Reproduced Quarter Size (½ Width and Height)

The actual form is to be on a standard letter-size sheet 8½ by 11 in. Horizontal lines under the heading and to the right of the record of engines in service, and the corresponding lines under "integrating wattmeters," to be ruled in blue; other lines in red.

(See next page)

(The following note is to be printed on the back of Form 2 of which it forms a part.)

Note: The time in service is to be indicated by a vertical line having its upper end at the time when the engine was started and its lower end at the time when the engine was stopped. The longest horizontal lines indicate the hours and the other lines indicate the quarter-hours. The indicating wattmeters should indicate the *power* being developed by the respective engine units. The integrating wattmeters should give the *work* delivered to the respective circuits. Inlet temperatures will probably be the same for all engines. Outlet temperatures, from all engines, should be read but need only be recorded in rotation. The integrating wattmeters and water-meter should be read at the same time each day.

This log is to be made up at the Station and signed by the Chief Engineer. It must reach the Office not later than noon of the day succeeding that for which the records are made.

line will be drawn from the line marking 12 o'clock midnight at the beginning of the day to 12 o'clock midnight at the end of the day.

7 The next three columns provide for recording hourly the pounds of fuel fired in each producer. Where this is not convenient, and the station is provided with means for keeping the 24-hr. consumption, the total quantity burned for that period can be placed as a footing at the bottom of the column; the hourly record is preferable, however.

8 The next six columns provide for recording hourly the gas pressure in inches of water at each producer and scrubber. The following three columns provide for recording the temperature of the gas leaving each producer. This is something which is not general practice, but your Committee believes the data to be desirable. On the right of the sheet, the amount of water consumed in the producer house is to be recorded. This amount is naturally and readily obtained by a standard form of water meter reading in cubic feet. The water meter should preferably be read at the same time each day; though whatever that hour may be is not material. The reading for the day reported upon is taken from the meter, the reading for the corresponding period for the previous day, or whenever the last reading was taken, is entered underneath, and the difference gives the quantity consumed for the intervening period. Below the water meter records, there is a space for recording the cubic feet of gas made during the day. Your Committee freely admits that it does not know of a meter to be recommended for this purpose, but strongly feels the data to be very desirable, and does know that several manufacturers are endeavoring to develop such a meter. The B.t.u. value of the gas, which follows the quantity record, should be obtained by means of a standard form of gas calorimeter such as is recommended by the American Gas Institute.

9 In this connection, it is desired to point out the fact that gas calorimeters, as ordinarily installed in gas power plants, are practically valueless. The calorimetry of gas is more in the nature of a laboratory operation than a power plant operation, and a gas calorimeter, to do good work, should be installed in a proper location of even temperature and free from dirt and drafts, and should be operated by a man who has been trained for the work, or at least instructed in the refinements of its operation.

10 The B.t.u. value of the fuel burned, which is the last quantity called for on the sheet, should be obtained by means of the ordinary coal calorimeter. Unlike the B.t.u. value of the gas, this need not be determined from day to day. The number and the frequency of the

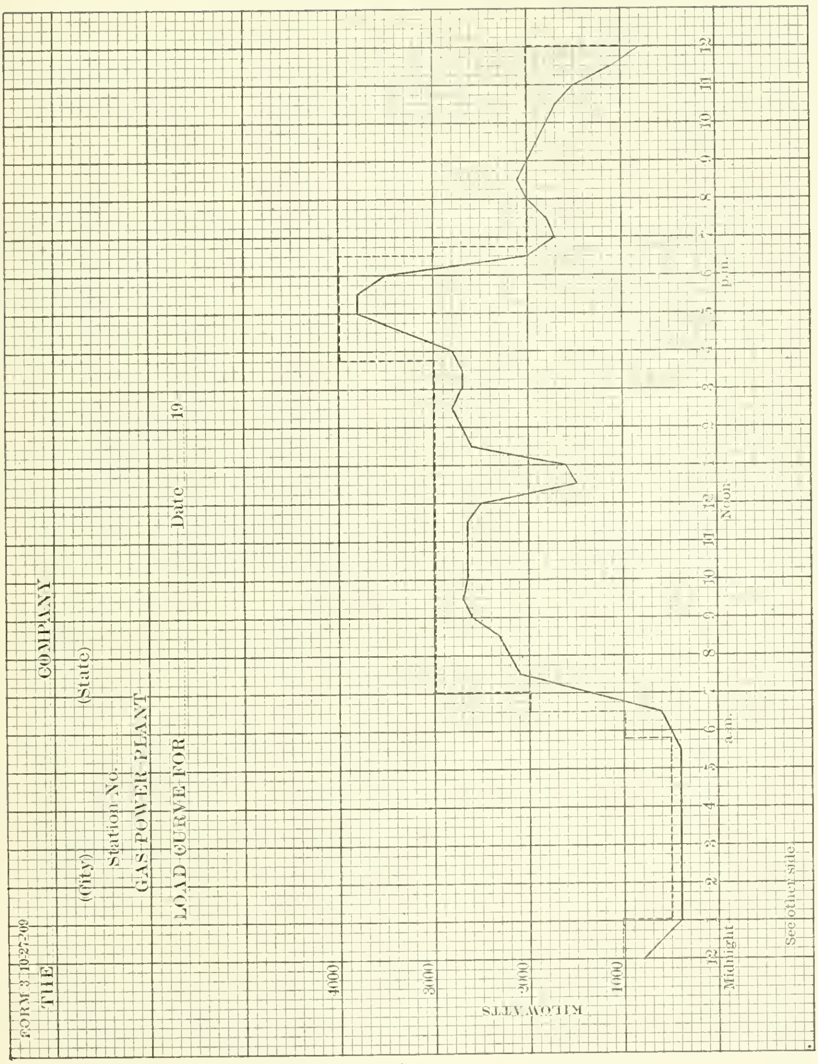
analyses must be determined by each operator, keeping in view the condition of his fuel supply.

11 At the bottom of the form is a space for remarks explaining any departure from the usual routine of operation. The sheet is then to be signed by the chief engineer and sent promptly to the company's office. On the back of the form is a note explaining its use to the station operators.

ENGINE LOG

12 The Engine Log serves a similar purpose for the engine room to what the Producer Log does for the producer room. At the left of the sheet, the run made by each unit is to be recorded in a way similar to the record of the producer units. Following these are three columns calling for hourly readings of the indicating wattmeters of each unit. The next three columns are for recording the temperatures of the cooling water, both entering and leaving the engine. The last column provides for the gas temperature at the throttle of the engine. At the bottom of the form, the readings of the integrating wattmeters of each unit for the 24-hr. period are to be recorded in a way similar to the water meter readings. There is also provision for integrating wattmeter readings covering all the auxiliaries in the station which are operated electrically. This latter quantity is usually small and your Committee does not deem it necessary to attempt to itemize it.

13 At the right of the sheet, space is provided to record the amount of cooling water used in the engine room. Following are spaces for recording the quantities of cylinder oil, engine oil and other lubricants, waste, and other supplies used in the plant. These supplies are intended to include those for the producer room as well as for the engine room. As the bulk of them are used in the engine room, it does not seem worth while to try to divide the amount between the two rooms. Doubtless many operators will find it inconvenient to keep a daily record of these supplies and with many small plants it might not be worth while to attempt such a record; in these cases, the supplies for a longer period of time can be recorded and then transferred to the Monthly Data Sheet. Your Committee, however, recommends a daily accounting where possible. Space is also provided for remarks by station operators, and as in the case of the Producer Log, the blank is then to be signed by the chief engineer and sent to the company's office. On the back are instructions to the operation people on the use of the form.



Form 3, Load Curve Form. To be 8½ by 11 in. Ruled in Blue

(SEE NEXT PAGE)

(The following note is to be printed on the back of Form 3 of which it forms a part.)

The dotted line shows the rated capacity of the units in service. The full line shows the load as plotted from the readings of the indicating wattmeters.

This curve is to be made up in the Office from data on Station Logs, at such intervals as the Company may determine.

14 In this connection, your Committee wishes to emphasize the fact that meter readings, thermometer readings, etc., are of little value unless accurate apparatus is provided and periodic inspections are made to determine their accuracy. Most of these devices, even with the best of care, will become inaccurate, and all should be checked at frequent intervals by careful men with reliable standards.

LOAD-CURVE FORM

15 The form for the load curve is prepared on standard cross-section paper ruled to tenths of an inch. The vertical scale represents load in kilowatts, its magnitude being determined by the capacity of the station. The horizontal scale represents time, each division indicating fifteen minutes. Your Committee submits a sample Load Curve Form to show how it should be plotted. The solid line is plotted from the readings of the indicating wattmeters as reported on the Engine Log. The dotted line shows the rated capacity of the units in service and is also plotted from the Engine Log. Superimposing these lines shows, at a glance, the character of the load and what units ought to be in operation to meet the demand. Your Committee recommends a load curve of the combined station instead of one for each unit.

16 The load curve may be plotted either in the station or in the office of the company, as may be most convenient. In many cases it will be required only at infrequent intervals, as, for instance, at a factory plant, where the character of the load does not change much from day to day. In the case of electric lighting and railway plants, daily load curves should certainly be made. With the Engine Log accurately filled out and kept on file, it would be a simple matter to make a load curve for any day in the past, if such were required, by referring to the file of station records.

MONTHLY DATA SHEET

17 The Monthly Data Sheet should be made out in the office of the company as early as possible in the next succeeding month. It is a summation of the daily data found on the Producer and Engine Logs, the pay roll of the plant, etc. At the top of the sheet, the normal capacity of the producers, engines and generators is to be filled in, and as these figures will be repeated from month to month, they will naturally be printed with the form when a company is ordering a supply

of blanks. Then comes a brief statement of the kind and size of coal used and the locality of the mine from which it is obtained. For the Class of Service, the work of the plant should be described, as electric-light plant, railway plant, factory, industrial plant or otherwise. A statement of the number of watches or shifts that a plant operates per day and the length of each shift in hours is then asked for.

18 Under the heading Producer Data, at the left of the sheet, column 1 calls for the total horsepower-hours of producers in service for each day of the month; column 2, the daily consumption of fuel in the producer house; column 3, the heat value of the fuel. If the latter is not changing, it is obviously unnecessary to fill this in daily. Column 4 is a summation of the water used in the producer house as measured by a commercial form of water meter.

19 Under Engine Data, column 5 calls for the total horsepower-hours of the prime movers in service during each 24 hours. Column 6 calls for the gas consumed, in cubic feet. As stated in the remarks on the Producer Log, it may be impossible for some plants to fill in this column at the present time. Column 7 calls for the calorific value of the gas. It will be noted that on both the Producer Log and the Monthly Data Sheet, your Committee specifies that this is to be the gross value. The gross value is used in these forms because the American Gas Institute has officially adopted it for use in all cases. It is realized, however, that it is still an open question whether a power plant should use the gross or the net heat value of the gas. It may be an injustice to charge the engines with something they are unable to use. Your Committee, therefore, suggests that this question be referred to the Gas Power Standardization Committee of the Society, and that the latter's opinion be obtained before these forms are formally adopted. Columns 9, 10, 11, 12, 13 and 14 are summations from the Engine Log.

20 Under the heading Load, column 15 calls for kilowatt-hours generated. This is to be interpreted to mean the gross kilowatt-hours delivered by the generators to the station bus bars as indicated by the recording wattmeters for the period, without any deductions being made for current used for station auxiliaries, lighting, etc. In column 16 is to be recorded the maximum load in kilowatts as shown by the hourly readings of the indicating wattmeters. In column 17 is to be recorded the power required by the electrical auxiliaries of the station as shown by their recording wattmeters. Two spare columns are left on the right-hand side of the sheet for data which may be required in special cases.

FORM 4. 10-27-'09

THE ______________________ COMPANY

(City) (State)

Station No. ___

GAS POWER PLANT

DATA SHEET FOR MONTH OF __________ 19 __

UNITS INSTALLED:

Gas Producer	(No.1 -- h.p. normal capacity (No.2 -- h.p. normal capacity (No.3 -- h.p. normal capacity	Engine	(No.1 -- h.p. normal capacity (No.2 -- h.p. normal capacity (No.3 -- h.p. normal capacity	Generators	(No.1 -- kw. normal capacity (No.2 -- kw. normal capacity (No.3 -- kw. normal capacity

Kind and size of coal used ______________________

Locality of mine ______________________

Class of service ______________ No. of watches ______________ Hours per watch ______

Date	Producer Data				Engine Data										Load			Misc.	
	H.P. HOURS IN SERVICE	FUEL IN LBS.	B.T.U. PER LB. OF COAL	PRO. WATER USED (CU. FT.)	H.P. HOURS IN SERVICE	GAS USED (CU. FT.)	B.T.U. OF GAS (GROSS VALUE)	TEMP. OF GAS AT THROTTLE (AVG.) DEGREES FAHR.	COOLING WATER USED ON ENG. (CU. FT.)	INLET TEMP. ENG. WATER (AVG.) DEGREES FAHR.	OUTLET TEMP. ENG. WATER (AVG.) DEGREES FAHR.	CYL. OIL (GALS.)	ENG. OIL (GALS.)	OTHER LUBS. (GALS.) (LBS.)	KW. HRS. GENERATED	MAX. LOAD IN KW.	KW. HRS. OF AUXILIARIES		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1																			
2																			
3																			
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31																			

LABOR:

	Chief Engineer	-- hrs. per day	Rate per hour per man
--	Producer men	-- " " "	" " " " "
--	Coal and ash handlers	-- " " "	" " " " "
--	Asst. Engineers	-- " " "	" " " " "
--	Oilers	-- " " "	" " " " "
--	Cleaners	-- " " "	" " " " "
--	Laborers	-- " " "	" " " " "
--	Repair men	-- " " "	" " " " "
--	Electrical operators	-- " " "	" " " " "

REMARKS:

See other side

FORM 4 MONTHLY DATA SHEET. REPRODUCED QUARTER SIZE (½ WIDTH AND HEIGHT)

THE ACTUAL FORM IS TO BE ON A SHEET 11 BY 17 IN. RULED IN RED WITH THE EXCEPTION OF THE HORIZONTAL LINES DIVIDING THE COLUMNS INTO DAYS. THE FOLLOWING NOTE IS TO BE PRINTED ON THE BACK OF THE SHEET:

Note: This form is to be filled out in the Office monthly from information contained in the daily Station Logs, Payroll, etc.

FORM 5 10–27–'09

THE ....COMPANY

(City) (State)

Station No.————

GAS POWER PLANT

COST SHEET FOR MONTH OF 19

OPERATION

SUPPLIES:

Fuel 000 tons @ $000.00 per ton of 2000 lb. (delivered alongside of producer and including disposal of ashes after removal from producer)..........	$
Water......cu. ft. @ 00 cents per M cu. ft...........................	$
Lubricants — Cylinder oil @ 00 cents per gal........................	$
Lubricants — Engine oil @ 00 cents per gal..........................	$
Lubricants — Other lubricants...	$
Waste and Miscellaneous Supplies..................................	$

LABOR:

Producer room..	$
Engine room..	$
Electrical..	$
....	
....	
TOTAL OPERATION........................	$

***REPAIRS**

LABOR AND MATERIAL:

Producers..	$
Producer room auxiliaries..................................	$
Main engines...	$
Engine room auxiliaries.....................................	$
*Electrical Equipment..	$
....	
....	
TOTAL REPAIRS...........................	$

SUMMARY:

Total Operation..	$
" Repairs..	$
TOTAL STATION COSTS......................	$

TOTAL KW. HRS.

Kw. Hrs. generated ....

" " used in plant......

Net Kw. Hrs. output.......COST PER NET KW. HR................ $

* See other side.

FORM 5, MONTHLY COST SHEET. TO BE PRINTED ON SHEETS $8\frac{1}{2}$ BY 11 IN.

(The following note is to be printed on the back of Form 5 of which it forms a part.)

Note: The entire cost of maintaining a plant should be separated into the cost of *repairs* and the cost of *replacements* and these headings should refer to *units of equipment* and not to *parts* of units. "Repairs" should include the renewals of such parts as grate bars, producer linings, piston rings, pistons, cylinders, valves, springs, igniter plugs, generator coils, armatures, etc. "Replacements" should include the replacement of old producers, engines, generators, etc., with new producers, engines, generators, etc., when the former are worn out or have become antiquated. "Replacements," in so far as their cost equals the original cost, should be paid for out of the depreciation fund. In so far as their cost exceeds the original cost, they should be paid for out of capital.

The cost of repairs to generators, exciters, switchboard apparatus, etc., should be entered under the sub-heading "electrical equipment." The cost of repairs to electrical auxiliaries such as motor-driven fans, motor-driven pumps, ignition outfits, etc., should be entered under the sub-heading "producer room auxiliaries" or "engine room auxiliaries" as the case may be.

This form is to be filled out in the Office monthly from information contained in the daily station Logs, Pay-roll, etc.

21 At the foot of the Monthly Data Sheet is a brief statement of the labor used in the plant. This is not intended to be a summation of the pay roll. It should show the total number of employees of each class, the number of hours constituting a day's work for each class, and the rate per hour paid to each class. In other words, this labor statement is intended to give an idea of the amount and quality of labor required in the plant and can be readily obtained from the station pay rolls. Following the labor statement, a space is left for general remarks. On the back of this form is a brief note explaining how it is to be used.

MONTHLY COST SHEET

22 The Monthly Cost Sheet is a financial summation of the operation of the plant. This is likewise to be filled out at the office of the company. The information is to be obtained from the Monthly Data Sheet, the pay rolls and the records of materials used during the month. Under the head of Operation, the first item calls for the number of tons of fuel, price per ton and total cost of fuel used per month. It will be noted that the word "fuel" is used in its broad sense, and the cost of fuel includes the disposal and removal of ashes. Some members have thought that the disposal of ashes should be a separate item. The opinion of the majority of the members of your Committee is that if the cost of fuel is to be analyzed, the cost of the disposal of ashes is one of the subdivisions, but that it is of no more importance than the freight on the fuel or the cost of handling the fuel, and it is believed that for the present at least it is not worth while attempting to itemize it. The water, lubricants, waste and miscellaneous supplies are all obtained from the Monthly Data Sheet and from the records of materials used during the month. Labor is obtained from the station pay rolls. The summation of the items under the head of Operation gives the total operating cost of the station for the month. Under the head of Repairs, quantities are likewise obtained from the Monthly Data Sheet, the pay rolls and the records of materials used during the month.

23 There has been some discussion about the item headed Repairs for Electrical Equipment. As the form is submitted this item includes all repairs to electrical equipment in the station, whether to main generators, electrical auxiliaries or switchboard apparatus. Your Committee believes that in the average small station it is not worth while to subdivide this item. In large stations it is desirable

so to do, and for such cases blank lines are left for subdivisions. The total of the items under Repairs covers the cost of up-keep for the month, which, added to the operating total, gives the total monthly cost of the station. Following this is a summation of the output of the station. The kilowatt-hours generated and those used in the plant are both obtained from the Monthly Data Sheet, their difference being the net output, which, divided into the total station cost, gives the cost per net kilowatt-hour for the month.

24 Your Committee wishes to call your attention to the note on the back of the Monthly Cost Sheet explaining just what it is desired to include under the heading Repairs. Many companies are not particular about separating the item of repairs from that of replacement; consequently repair data are misleading and often of little value.

25 As this Committee is a plant operations committee it has endeavored to eliminate entirely everything not strictly operating. Some members have criticised the Cost Sheet because it did not include managerial expense, taxes, repairs to buildings and other items of this character. Your Committee feels that these belong properly to the subject of financial expense rather than operating. It is true, for instance, that a power plant must be housed and that it should be charged with the cost of building. The character of the buildings, however, varies so widely, and the cost of the real estate upon which they are built is so much a question of location rather than of the design and operation of the plant, that comparison of these figures means nothing without a knowledge of many details concerning them. Your Committee therefore feels it is wise, at this time, to omit such items.

26 Since these forms were virtually completed, Mr. Davidson of this Committee was fortunately enabled to discuss the proposed Cost Sheet at length, with Mr. Duffy, comptroller of his company, the Milwaukee Electric Railway and Light Company, and with Mr. Hagenah of the Wisconsin Railroad Commission. These gentlemen have kindly given much thought to the proposed forms and have made a number of radical suggestions. Time did not permit your Committee to make full use of these suggestions, but as they are based on wide experience (the Wisconsin Railroad Commission in particular having done a great deal of work on the subject of accounting for public utilities companies) it seems that some consideration should be given to their suggestions. The forms proposed by these gentlemen, together with an abstract of a letter from Mr. Hagenah giving

FORM 6 10–27–09

THE ....COMPANY

(CITY) (STATE)

STATION NO. ....

GAS POWER PLANT

DETAILS OF PLANT

PRODUCERS:

Number.........................Suction or pressure.................

Inside diameter...................Type of bottom.....................

Height of fire-bed.................Thickness of lining.................

Wet Scrubber; type...............Size.............................

Dry Scrubber; type...............Size ....

Vaporizer; type..

GAS ENGINES:

Number.........................Horizontal or vertical.............

R. p. m.........................Single or double acting.............

Type of cycle....................How connected to load...........

Cylinders; number................Arrangement...................

Diameter and stroke of pistons.................................

Compression (by indicator) ....Clearance (% of displacement).....

Number of bearings rigidly in line...............................

How started......................Air pressure.....................

Type of ignition..................Source of ignition supply..........

AUXILIARIES..

....

....

REMARKS...

....

....

FORM 6, DIMENSION BLANK. TO BE PRINTED ON SHEETS $8\frac{1}{2}$ BY 11 IN.

his arguments in support of the forms they recommend, are therefore contained in Addendum A to this report.

27 About the same time, Mr. Freyn of this Committee called attention to the fact that the forms as proposed did not conveniently meet the blast-furnace gas plant requirements, which is perfectly true. Your Committee had considered that blast furnace gas plants are in a class by themselves, requiring quite different treatment. Most of these plants are adjuncts of large manufacturing corporations which now have their own forms and records. Mr. Freyn, however, was appointed special subcommittee of one to submit forms for blast-furnace gas plants and has submitted forms which also were received too late for your Committee to give them careful attention. They are submitted as Addendum B to this report.

CONCLUSION

28 Your Committee realizes that, in attempting this work, it is trying to accomplish something that has never before been done, namely, to prepare a set of forms to be adopted and used generally by people many of whom are operating gas power plants, not as their principal business, but as a small and necessary adjunct. It is felt that, at least for the present, these forms should be simple, concise, easily kept and so designed that when they are properly kept, they will be of value to the people keeping them. Many operators today keep no records, and if they were approached with an elaborate set of forms each containing many items, they would doubtless refuse to use them on the ground that the expense and inconvenience involved is not warranted by any possible saving. To meet this situation, it has been the intention to err, if at all, in the direction of simplicity. If a set of forms can be prepared which will meet the approval of a large number of power plant operators and be adopted by them, a big step will have been made. The use of these forms for a short time, by a number of concerns of varied character and interest, will quickly demonstrate where they should be altered. It does not at all follow that these forms cannot, in many instances, be elaborated upon at the start, and should a particular operator find that certain items of which he desires to keep a record are not mentioned, it is a simple matter to add such items to the forms submitted.

29 Referring to the forms in Addendum A submitted by Messrs. Davidson, Duffy and Hagenah, your Committee feels that they are itemized more than is necessary for the present, and generally do not

fit the requirements of the work as well as those contained in the report itself. It might possibly be well to give more time to these forms, conferring with the Wisconsin Railroad Commission and other State commissions having jurisdiction over similar accounts in their respective commonwealths, before these forms are finally adopted. It should be borne in mind, however, that a State commission has certain authority regarding what data should be kept and how, while your Committee possesses no such authority and its forms must have sufficient merit to win their own way. Your Committee would also like to point out the fact that a committee consisting of twenty members scattered over a wide range of territory is very unwieldy, especially in work of this character which does not permit of subdivision. Should it be desired to continue the committee it is believed that the work would be greatly facilitated by radically reducing the number of members.

Respectfully submitted

I. E. Moultrop, *Chairman*

J. D. Andrew	J. L. Lyon	
W. H. Blauvelt	V. E. McMullen	
V. Z. Caracristi	V. T. Macleod	
E. P. Coleman	C. H. Parker	
C. J. Davidson	J. P. Sparrow	*Plant Operations Committee*
W. T. Donnelly	A. B. Steen	
H. J. K. Freyn	F. W. Walker	
N. T. Harrington	C. W. Whiting	
J. B. Klumpp	Paul Winsor	
G. L. Knight	T. H. Yawger	

ADDENDUM A

MONTHLY COST SHEET FORMS

Submitted by Messrs. Davidson, Duffy and Hagenah

These forms are submitted by the above named gentlemen as in their opinion superior to those offered by your Committee. They are probably best explained by quoting direct from Mr. Hagenah who writes in regard to them as follows:

After studying the form it appeared to me that while it contained some excellent features in the separation of expenses between Operation and Repairs and these in turn subdivided between Supplies and Labor, my first criticism would be that the blank does not go far enough in the application of these principles. If the object of this blank is to show the cost of electric energy generated by gas power, it should also show, in so far as this is possible, the cost of all elements entering into such final figures. Of primary importance among these items is the cost of power gas. This expense is likewise divisible into the expense of Operation and the expense of Maintenance and these in turn consist of Labor and Supplies.

I have always maintained that the principle of cost accounting, showing the cost of each process in the chronological and natural order of production, should be adhered to wherever possible and departed from only for good reasons. It appears to me that every station engineer would wish to know for his own guidance and satisfaction the cost of so large an item of expense as the gas produced for power purposes. More particularly is this desirable in the case of those plants in which the total amount of gas produced is not used for electric generation, but is produced for the benefit of two or more departments. The blank which you have submitted to me does not admit of this separation and analysis, and since nearly every account contains some gas production expense and some electric power expense, I am inclined to believe the blank would not lend itself to the satisfactory use of some of the larger plants in this state.

In this connection I recall several conferences which were had prior to the final adoption of the present Wisconsin uniform classifications of accounts for the different utility services. When I say that these conferences were attended by engineering and accounting representatives of some of the largest gas and electric plants in the United States, and that this method of separation of accounts received the most thorough discussion and was finally agreed to by them and incorporated in the Wisconsin official classifications, I may be pardoned for submitting the enclosed blanks which recognize the above features and therein go further than the blanks prepared by the Plant Operations Committee.

In defense of the enclosed blanks I beg to call your attention to the fact that they permit of the separate cost analysis; apply equally to plants whose total gas production is used for electric generation or apportioned over several departments; and constitute an elastic outline which can be followed by plants of all sizes. The smaller plants may combine the details of Labor, Supplies and Maintenance into but three accounts, if necessary, while the larger plants can subdivide the accounts given to the greatest degree of refinement without destroying the

basis for comparative statistical study. In regard to the definitions of terms used in these forms and the text of instructions therefor, together with the apportionment of the final cost of production, I beg to refer you to the text of instructions accompanying the Wisconsin classification of accounts for electric utilities, to which classification these blanks conform with the exception of several account titles and subdivisions, in which respect I believe the outline of the Plant Operations Committee is preferable.

The following are some changes which I wish to call to your attention:

The outline of the Plant Operations Committee makes no mention of the cost of removing residuals from buildings. I presume the text of instructions for the blank would cover this point. I prefer the account title Lubricants to Oil in view of the fact that Lubricants is a broader term and I am informed that other lubricants than the two kinds of oil mentioned may be used. This, however, may not be very important. In a large plant I believe it would be advisable to determine separately Maintenance of Generators as distinct from Maintenance of other Electrical Equipment. Small plants could easily combine these two if necessary. The account Removal of Ashes is an improvement over the Wisconsin system. I have added the accounts Maintenance of Producer Buildings, Fixtures and Grounds, Maintenance of Power Plant Buildings, Fixtures and Grounds, for which no provision is made in the outline of the Plant Operations Committee.

The recommended forms follow on the two succeeding pages.

FORM 1 ADDENDUM A

....COMPANY

CITY.......................................STATE.............. .....

GAS PLANT MONTHLY COST SHEET FOR............,19 ....PLANT NO.....

PRODUCER PLANT AND BY-PRODUCT PLANT

	Amount	Cents per M. Cu. Ft. Gas Produced
Gas and By-Product Production-Operation:		
1 Producer-Plant Operating Labor (Including Superintendence, Fuel Handlers, Producer Plant Labor, Ash Handlers, Miscellaneous Labor, Pumpmen, Water Purification Labor)		
2 By-Product Plant Operating Labor (Including Superintendence, Residual Handlers, Miscellaneous Labor)		
*3 Fuel (Average B.t.u. For one cent............)		
**4 Water (..........cents per M cubic feet)		
5 Removal of Ashes Expense (Haulage; Debit in black, Credit in red)		
6 Producer Plant, Miscellaneous Supplies and Expenses		
7 By-Product Plant, Miscellaneous Supplies and Expenses		
Total Operation		
Gas and By-Products Production-Maintenance:		
8 Producers and Producer Auxiliary Equipment		
9 By-Product Plant Equipment		
10 Coal and Ash-Handling Equipment		
11 Producer Plant Buildings, Fixtures and Grounds		
12 By-Product Plant Buildings, Fixtures and Grounds		
Total Maintenance		
Total Cost of Gas and By-Product Production		
Value of Residuals and By-Products		
Cost of Gas Production (..........cu. ft.)		
***Distribution of Gas Production:		
Electric Generation		
Sales		
Other Purposes		

* Define kind of fuel used, whether coal, coke, lignite, peat wood, or oil, giving unit cost of same to be expressed in Average B.t.u. for one cent. The cost of Fuel to cover cost in storage, including delivery to place of storage; also Fuel Stock Expense, cost of weighing, unloading and handling fuel for storage, covering unloading of fuel from cars, boats or wagons, including cost of the operation and maintenance of scales, hoisting apparatus, cost of shovels or other hand-tools used in the work. Fuel Stock Expense should be closed into Fuel Stock Account.

** Water should be clearly defined as to whether it is the cost of water purchased, the expense of pumping water (to include the cost of the operation and maintenance of the pumps and pumping equipment), or the expense of purifying water (to include the cost of operation and maintenance of the water purification equipment), or all of these. The unit cost of the water used should be expressed in cents per M cubic feet.

*** If the gas produced is used for more than one purpose, for example, for Electric Generation, Sales, or Other Purposes, in the case of a company which makes such uses of its product, the Gas Production should be apportioned to Electric Generation, Sales, or Other Purposes, in the proportion of the use of same for each of the purposes respectively.

Note:—If Fuel Stock Expense, Expense of Pumping Water, or Expense of Purifying Water, as defined above, cannot be ascertained or determined, or if the amounts involved do not justify the use of the accounts Fuel Stock Expense, Expense of Pumping Water, or Expense of Purifying Water, then such accounts are not to be used and the expenses chargeable to said accounts

should be included in such other accounts as the nature of the expenses would properly determine, presumably in account No. 1, Producer-Plant Operating Labor, account No. 6, Producer Plant Miscellaneous Supplies and Expenses, account No. 8, Maintenance of Producers and Producer Auxiliary Equipment, account No. 11, Maintenance of Producer Plant Buildings, Fixtures and Grounds, or account No. 12, Maintenance of By-Product Plant Buildings, Fixtures, Grounds.

FORM 2 ADDENDUM A

....COMPANY

CITY..................................STATE..............

GAS POWER PLANT MONTHLY COST SHEET FOR.........19......PLANT NO.......

PRIME MOVER PLANT

	Amount	Cents per S. B. Kw-Hr. Output
Electric Generation-Operation:		
1 Prime Mover Plant Operating Labor (Including Superintendence, Prime Mover Labor, Electrical Labor, Miscellaneous Labor)		
2 Power Gas Produced (See Producer Plant Sheet for Details)		
3 Power Gas Purchased (........cu. ft. at $........ per M)		
*4 Water for Cooling Engines		
5 Lubricants (Cylinder Oil......cents per gal., Engine Oil......cents cents per gal., Other Lubricants......cents per lb.)		
6 Miscellaneous Supplies and Expenses		
Total Operation		
Electrical Generation-Maintenance:		
7 Prime Movers (Engines, Turbines, other Prime Movers)		
8 Prime Mover Auxiliary Equipment		
9 Generators and Auxiliary Generating Equipment		
10 Miscellaneous Prime Mover Plant Electrical Equipment (Switchboards and Equipment Cables, Feeder Terminals, Wiring other than for buildings chargeable to account No. 11, Miscellaneous Electrical Equipment other than covered in account No. 9)		
11 Prime Mover Plant Buildings, Fixtures and Grounds		
Total Maintenance		
Total Electric Generation:		
Kilowatt-Hours Generated		
Kilowatt-Hours Used in Plant		
Kilowatt-Hour Output at Switchboard		
** **Distribution of Kilowatt-Hour Output:**		
Electric Railway System		
Electric Light and Power System		
Other Purposes		

* Water should be clearly defined as to whether it is the cost of water purchased, the expense of pumping water (to include the cost of the operation and maintenance of the pumps and pumping equipment), or the expense of purifying water (to include the cost of operation and maintenance of the water purification equipment), or all of these. The unit cost of the water used should be expressed in cents per M cubic feet.

Water used for other purposes than Water for Cooling Engines should be charged to account No. 6, Miscellaneous Supplies and Expenses.

** If the electrical energy generated is used for more than one purpose, for example, for an Electric Railway System, an Electric Light and Power System, or for Other Purposes, in the case of a company operating such a diversified system, the electrical energy should be apportioned

to The Electric Railway System, The Electric Light and Power System, or Other Purposes, in the proportion of the use of same by each of the systems respectively.

Note:—If Expense of Pumping Water or Expense of Purifying Water, as defined above, cannot be ascertained or determined, or if the amounts involved do not justify the use of the accounts, Expense of Pumping Water or Expense of Purifying Water, then such accounts are not to be used and the expenses chargeable to said accounts should be included in such other accounts as the nature of the expenses would properly determine, presumably in account No. 1, Prime Mover Plant Operating Labor, account No. 6, Miscellaneous Supplies and Expenses, Account No. 8, Maintenance of Prime Mover Auxiliary Equipment.

ADDENDUM B

FORMS FOR BLAST-FURNACE GAS POWER PLANTS

Submitted by Mr. Freyn

The following forms which have been submitted to the Committee by Mr. H. J. K. Freyn show his proposed modifications to make the forms suit blast-furnace gas plant conditions. Before these forms are adopted they should, of course, be made on the standard-size sheets recommended in the body of the report. A few suggestions made by Mr. Freyn about his proposed forms are contained in the following extract from his letter to the Chairman of the Committee:

Please note additions made on cost sheet for month, pertaining to cost per kilowatt-hour of various items.

The sheet headed Gas Power Plant covers the gas washing machinery, and number of washers in service, both primary and secondary systems; and gives additional columns of valuable information, such as temperatures, power and water consumption, etc.

The other sheet, headed Gas Power Plant, gives the Gas Engine log, which, of course, is identically the same as for a producer power plant, while it would be advisable to add something as to the cause of shutdowns.

One sheet I added covering the daily chemical report, such as is being kept at this plant, which I find to be of great value.

The data sheet for the month is merely an adaptation for a blast-furnace gas power plant.

The load-sheet curve should preferably be a daily instead of an hourly curve for large power plants in steel works, because the load conditions do not change as radically as in smaller gas power plants.

I do not think that a big power plant can be induced to get up hourly load curves for each day.

One thing that would probably be very desirable is to get up curves showing some of the information given on the data sheet for the month. As a matter of fact the plotting of this and similar information I have found to be very much better and clearer than a compilation of figures. The curve will naturally show any changes in conditions mnch better than the mere figures.

2 Considering the forms in detail, the Gas Cleaning Plant Daily Log serves a similar purpose to the Producer Log of the producer

plant. The Daily Chemical Report is an entirely new form which is justified by the possibility of large variation in the quality of gas and the amount of dust and moisture contained therein. The Engine Log requires no change, consequently the form in the body of the report is applicable in both cases. The space for remarks on the Gas Engine Log is intended to include such information as Mr. Freyn mentions in his letter. The Load Curve Form submitted in the report is obviously perfectly well adapted for the blast-furnace gas plant and is eliminated from the following set of forms. If a load curve for a longer period than twenty-four hours is desired, the form submitted in the body of the report can be used by merely changing the magnitude of the horizontal scale. The Monthly Data Sheet is practically the same as that for a producer plant with the exception that the first few columns are changed to record the daily data from the washing plant. The Monthly Cost Sheet likewise contains very little change from the same sheet of the producer plant, the main items in both cases being the same. The forms are given on the succeeding pages and accompanying folder.

FORM 1 ADDENDA B 10-27 '09

______________ WORKS ______________ COMPANY

GAS POWER PLANT

GAS-CLEANING PLANT—DAILY LOG FOR 24 HRS. ENDING 6 a.m. 19

Time	Washers in Service								Gas-Temperatures and Pressures								Power Consumed by Gas. Cl. Plant		Water Used Gal per Min.		Gas Consumed Cub. Ft. per Min.
	Primary				Secondary				Before Clean'g Plant		After Primary Clean'g		After Secon'y Clean'g		At Holder						
	1	2	3	4	1	2	3	4	P	T	P	T	P	T	P	T	1st	2nd	1st	2nd	
6 a.m.																					
7 a.m.																					
8 a.m.																					
9 a.m.																					
10 a.m.																					
11 a.m.																					
12 m.																					
1 p.m.																					
2 p.m.																					
3 p.m.																					
4 p.m.																					
5 p.m.																					
6 p.m.																					
7 p.m.																					
8 p.m.																					
9 p.m.																					
10 p.m.																					
11 p.m.																					
12 night																					
1 a.m.																					
2 a.m.																					
3 a.m.																					
4 a.m.																					
5 a.m.																					
6 a.m.																					
Total [illegible] Avg. Temp. Press. [illegible]																					

PROPOSED DAILY LOG FOR GAS-CLEANING PLANT FOR BLAST-FURNACE GAS

TO BE ON A STANDARD LETTER-SIZE SHEET $8\frac{1}{2}$ BY 11 IN. HORIZONTAL LINES UNDER THE HEADING AND TO THE RIGHT OF THE RECORD OF WASHERS IN SERVICE TO BE RULED IN BLUE; OTHER LINES IN RED

FORM 3 ADDENDA B 10-27-'09

------------ WORKS ---------------- COMPANY

Class of Service ------------------ GAS POWER PLANT

No. of Watches ------ Hrs. per Watch --------- DATA SHEET FOR MONTH OF ------------ 19 ----

ENGINES 1 -------- h.p. capacity
2 -------- " "
3 -------- " "
4 -------- " "

Date	Max. Prim'y Washers	Max. Sec'ry Washers	Total Prim'y Wash'r Hrs.	Total Sec'ry Wash'r Hrs.	Gas Consumed Cu. Ft. 1 Min.	B.T.U. per Cu. Ft.	Water to Primary Washers Gal. per Min.	Water to Secondary Washers Gal. per Min.	No. of Hours in Operation Engine				Average Kw. Engine				Gas Temp. at Throttle	Cooling Water			Gal. Oil Used		Air Temp.	Barometer	
									1	2	3	4	1	2	3	4		Inlet Deg. F.	Outlet Deg. F.	Gal. per Min.	Cyl.	Eng.			
1																									
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28																									
29																									
30																									
31																									
Avg.																									

MONTHLY DATA SHEET FOR BLAST-FURNACE GAS PLANT

TO BE ON A SHEET 11 BY 17 IN. HORIZONTAL LINES UNDER THE HEADING TO BE RULED IN BLUE; OTHER LINES IN RED

FORM 2 ADDENDA B 10-27-'09

______________ WORKS ______________ COMPANY

GAS POWER PLANT

DAILY CHEMICAL REPORT FOR 24 HRS. ENDING 6 a.m. ____ 19

Standard Conditions 62° Fahr. 30″ Mercury

Time	Gas Analysis						B.T.U. by Calorimeter	Flue Dust Gr's. per Cu. Ft.			Moisture Grains per Cu. Ft.				Temp. of Air	Barometer	
	CO	CO_2	H	CH_4		B.t.u.		Before Primary Washers	After Primary Washers	In Engine Gas	Before Primary Washers	After Primary Washers	In Engine Gas	In Air			
9 a.m.																	
12 m.																	
3 p.m.																	
6 p.m.																	
9 p.m.																	
12 ngt																	
3 a.m.																	
6 a.m.																	
Average																	

Per Cent of dust removed by Primary Washers ________

Per Cent of dust removed by Secondary Washers _____

REMARKS.

PROPOSED FORM FOR DAILY CHEMICAL REPORT, FOR BLAST-FURNACE GAS PLANT

TO BE ON STANDARD LETTER-SIZE SHEET $8\frac{1}{2}$ BY 11 IN. HORIZONTAL LINES UNDER HEADING TO BE RULED IN BLUE; OTHER LINES IN RED

Form 4 Addenda B 10–27–'09

WORKS ....COMPANY

Gas Power Plant

Cost Sheet for Month of..................19

	Cost total	Cost per kw hr
Operation		
supplies		
Gas @ $.... per 1000 cu. ft delivered to gas cleaning plant....................................	$.	$.
Water @ $....¢ per 1000 gal........................	$.	$.
Oil, cyl. @ $....¢ per gal..........................	$.	$.
Eng. @ ....¢ per gal..........................	$.	$.
Waste and misc. supplies	$.	$.
labor		
Gas cleaning plant....................................	$.	$.
Engineers, Oilers, etc............................	$.	$.
Electricians..	$.	$.
Total Operation Cost....................	$.	$.
Repairs		
Gas-Cleaning Plant..............................	$.	$.
Gas Engines......................................	$.	$.
Dynamos..	$.	$.
Engine Auxiliaries..............................	$.	$.
Building and Misc..............................	$.	$.
Total Repairs....	$.	$.
Total Operation and Repairs................	$.	$.
Plant Output, kw. hrs.		
Kw-hrs. Generated		
" " For Auxiliaries		
Net kw-hrs. Output		

Proposed Form for Cost Sheets. To be Printed on Sheets $8\frac{1}{2}$ by 11 in.

PRELIMINARY REPORT OF THE STANDARDIZATION COMMITTEE

At the first meeting of the Gas Power Section of The American Society of Mechanical Engineers, held in the Society rooms February 11, 1908, following a paper on Gas Engine and Producer Guarantees, on motion of H. L. Doherty the chairman was empowered to appoint a committee with himself as chairman to standardize so far as seemed practicable the use of terms and the practice of making guarantees of performance for gas engines and producers and the determination of their fulfilment. Accordingly the following committee was named: C. E. Lucke, *Chairman*; H. F. Smith, Louis Doelling, E. T. Adams, J. D. Andrew, J. R. Bibbins, A. West.

2 The duty of the committee was to consider the loose practices which are natural to an industry so young and advancing so rapidly into unknown fields. These bad practices include, besides guarantees of unattainable quantities, incomplete guarantees or guarantees of unmeasurable quantities; or of those measurable in various ways, each of which may give different results, besides incomplete statement of fundamental conditions; all traceable to (*a*) ignorance; (*b*) a not very commendable preference for an indefinite statement that leaves a loophole in case of non-compliance; (*c*) possibly in some rare cases direct intent to deceive. While with the most reputable builders there are cases of honest difficulty, as in the interpretation of the calorific power of gas, the distinction between high and low values and the definition of tar and gas impurities, most of the trouble is with builders who depend on copying previous machines, basing the guarantee of their untested apparatus on hearsay performance of others.

3 Practice due to ignorance or intent to deceive being unprofessional, and injurious to the legitimate development of a new power system which promises more for the conservation of national fuel resources than anything else ever proposed, it is proper that the committee seek to improve the state of affairs by

a Making certain general recommendations acceptable to all good engineers.

b Defining specifically those terms or conditions, the interpretation of which seems to be a matter of agreement and practice.

c Pointing out just where the difficulty lies in the remaining cases, in which, due to insufficient progress, there is not complete understanding or agreement; that due caution may be exercised by all in avoiding misunderstanding.

4 Besides the individual opinions of the committee, some of which were published in The Journal (September 1908, p. 895), as a Progress Report, many builders and their engineers have been consulted, as well as purchasers and in some cases lawyers employed in cases of alleged non-fulfillment arising from the conditions noted; and at more than one meeting of the American Gas Power Society, the questions at issue have been discussed and other opinions obtained.

5 Many of the questions under consideration tend to settle themselves with a proper test code, and the report of the committee has divided itself into (*a*) recommendations not properly part of a code of tests, but related to such a code because many of the most important terms could be definitely fixed only by fixing a mode of measurement; (*b*) a code of tests which would prescribe the procedure for the determination of all quantities entering into the fixing of capacity, efficiency and regulation of both engines and producers.

6 Before effective steps towards the most difficult work of code preparation could be taken, however, a new committee was appointed by the President after the Detroit meeting to codify the testing of gas power apparatus. This committee was discharged before its work had progressed far enough to coöperate with the Standardization Committee; and it was succeeded, on its own recommendation, by a third committee for the revision of all power tests in order to avoid conflict of procedure with necessary new codes, of the various existing codes, either in their original or in revised form.

7 This last committee has held two meetings, but is not as yet in a position to coöperate with the Standardization Committee; this preliminary report is therefore subject to revision when the new gas power code is completed, and its provisions will probably be incorporated in the report. With a complete gas power test code references to these provisions might be very brief; but this code is not in existence and the old gas engine code is of little help, while there exists no producer code at all: references to code procedures are therefore rather full in this preliminary report.

8 To avoid direct conflict with any code, the procedure of direct measurement of important quantities to be defined by that procedure is not recommended but the difficulties and alternatives are pointed out. On the assumption that a gas power plant when bought is adapted to do something, when supplied with some available f el, at a certain rate in pounds of fuel per hour, it may be assumed that guarantees for this class of apparatus will include capacity, efficiency and regulation, of gas producers and engines or complete plants, with auxiliary apparatus included, either as such completely, or in part, or in effect completely or in part, with or without specific reference to the adaptability of the apparatus to the service, and of the coal or gas to the producer or engine.

9 As the capacity of a unit may be considered as generically its output in some unit, and its efficiency the ratio of output to input in the same units, capacity and efficiency of producers and engines or complete plants will be defined when definitions are fixed for:

A Input of producers.
B Output of producers = input of engines (when all gas generated is taken by the engine).
C Output of engines.

To these must be added a definition of regulation of each unit and adaptability or suitability of fuel supply to the needs of the unit.

D Regulation of producers.
E Regulation of engines.
F Adaptability of coal for producers.
G Adaptability of gas for engines.

10 *A* The input of producers is defined by quality of coal and quantity consumed per hour, or B.t.u. per hour in the form of coal or in its identical horsepower equivalent.

11 *B* The output of producers and the input of engines is defined by quality of gas and quantity per hour, which should be taken in connection with the time it can continue, or B.t.u. per hour in the form of gas or its identical horsepower equivalent.

12 *C* The output of an engine is defined by its horsepower or identically equivalent B.t.u. per hour, which should be taken in connection with the time it continues.

13 *D* The regulation of producers is defined by the relative or absolute variation of gas quality at any one of several constant rates of output or at any acceleration rate, positive or negative, of gas

discharge lasting for any time, assuming an always available fuel supply proper in quantity and quality.

14 *E* The regulation of engines is defined by the relative or absolute variation of speed, in terms of complete revolutions in one minute, and by the constancy of its angular velocity or rate of completion of any part of a turn or number of turns, at one of several rates of output or horsepower load, and at any positive or negative acceleration of load lasting for any time, assuming an always available gas supply proper in quantity and quality.

15 *F* The adaptability of coal for producers is defined partly by (*a*) the capability of the producer to gasify it successfully, without undue interruption of service, destruction of apparatus or excessive labor in adjustment or management, comparatively as well as some other fuels considered satisfactory and adopted as a standard; (*b*) the relation of its physical and chemical condition to the peculiar needs of the producer.

16 *G* The adaptability of gas for engines is defined partly by quality and partly by (*a*) characteristics which enable the engine of proper design to use it successfully without undue interruption of service, destruction of parts, excessive labor in adjustment or management, comparatively as well as some other considered satisfactory and adopted as a standard; (*b*) the relation of its physical and chemical condition to the peculiar needs of the engine.

17 This analysis shows that definition of the five general terms or essential conditions is to be accomplished only by defining:

a Quality of coal and variation in quality and rate of change of consumption.

b Quantity of coal consumed per hour by producers.

c B.t.u. equivalent of a given quantity of coal of defined quality.

d Quality of gas and variation in quality.

e Quantity of gas per hour delivered by producers or supplied to engines, and rate of change of delivery or supply.

f B.t.u. equivalent of a given quantity of gas of defined quality.

g Horsepower of engines and variations in horsepower.

h Consecutive time producers may continue to deliver gas of defined quantity and quality, or engines to deliver defined horsepower.

i Number of revolutions, partial or complete, in any time

interval, and change in number with change of time interval chosen or with load conditions of engine.

j Time-interval for the completion of any number of revolutions, or fractions of revolutions, and the change in the time-interval with the number of revolutions chosen for observation or with load conditions of engine.

k Physical or chemical condition of coal, not included in quality definition but affecting adaptability to producer.

l Physical or chemical condition of gases not included in quality definition but affecting adaptability to engine.

QUALITY OF COAL AND ITS VARIATION IN QUALITY

18 Expressions for the quality of coal may be based on a sample as fired, which will be more or less wet; on a sample dried at 210 deg. fahr., or just below the atmospheric boiling point; on a sample heated to a temperature high enough to drive off fixed water, such as water of crystallization, especially important in some lignites. The result will be different in each case, the differences being more important in gas producers than in boilers, as the water vapor from the coal in the producer may pass off as steam, robbing the fire of its total heat as superheated steam above the temperature before firing, or it may react in the fire with carbon, or simply dissociate wholly or in part. Further differences result from the non-uniformity of quality of various samples from the same pile, or successive lots from the same mine, as well as from variations in size, especially in the case of small anthracites. Anthracite of pea size will not have the quality of the same coal of rice size, because of dirt, while mixtures sold for one size will constantly differ from each other, especially when the products of different mines and washeries are compared.

19 With these possibilities of fluctuations in results of expressions for quality, it is clear that rigid limitation to definition of quality of coal, in whatever terms, will be practically impossible. Quality may be expressed by:

a Ultimate analysis, which indicates the quantities of the elements present to enter into the producer reaction; but there is no certainty how they will enter, as, for example, C may be in the form of a hydrocarbon, fixed gas or tar, easily decomposed to lamp black, at the producer temperature or not.

20 While, then, the ultimate-analysis method of defining a coal seems to indicate what is present for the reaction, and so to permit of a judgment of the kind of gas that may result, in reality it does not, nor does it give any clue to the behavior of the coal in the producer.

b Proximate analysis, which gives fixed carbon, volatile, moisture lost at some temperature, and ash, offers a somewhat better indication of behavior; but the nature of the volatile may be widely different, in some cases being almost entirely fixed gas, as for example, CH_4; in others including other hydrocarbons of the tarry order, a variation may have serious consequences.

21 Moreover, there is no standard temperature at which the determination for volatile or moisture is to be made. It is well known that some coals do not yield all their volatile until the fixed carbon cell walls are broken down or weakened by combustion at very high temperatures, while others give off practically all their volatile at fairly low temperatures. While the proximate analysis yields more information concerning the probable behavior of the coal in the producer than the ultimate analysis, it does not permit of any judgment of the gas, or the quality of the coal for the purpose, nor of the heat that the coal may yield.

c Calorific power by calorimeter test is a valuable characteristic, but as different instruments yield different results on parts of the same sample a fair margin of fluctuations must be permitted.

22 In all cases the products of combustion are cooled to their original temperature. When water is formed from the combustion of hydrogen the latent heat of condensation is added and also the heat of the liquid from condensation temperature down to original, except for so much water vapor as will saturate the gases of combustion at the final pressure and temperature. The results of the tests show, within perhaps one or two per cent, the heat to be expected per average pound of coal of the same condition as the sample; this is one of the most valuable characteristics of the coal, though alone it shows little about the adaptability of the coal to producers.

d Calculation of calorific power by empiric formula is no better than the formula and its constants; and as no formula has been found adapted to all classes of coal, giving results in reasonably close agreement with calorimeter test,

the formula must be regarded as a crude approximation, not, is agreed upon as acceptable to the contracting parties.

RECOMMENDATIONS

23 As ordinarily the owner must burn what coal he can buy cheaply, and as coal is usually described by mine name or trade name only, unless the builder of the producer has apparatus at work on the same coal or conditions of equipment, and can arrange for a preliminary trial, no guarantee can be written except by the merest guess. Even were all the quality characteristics known, it is doubtful whether conditions would be much better, *except when the producer builder recognizes them as equivalent to those of another coal, successfully used in his apparatus in another place.*

24 These characteristics of coal expressing its quality are then valuable, and when taken in connection with adaptability characteristics are quite conclusive evidence of *identity*, though they do not permit of prediction. It is therefore recommended:

A That coal quality be defined by (*a*) ultimate analysis of samples dried at 210 deg. fahr.; (*b*) proximate analysis of samples dried at 210 deg. fahr.; (*c*) calorimeter test by a to be avoided unless some formula, whether correct or specified calorimeter, such as Parr, Mahler, Atwater.

B That this definition of quality be considered as a mark of identity with some coal successfully gasified by the producer in question, and not in itself a measure of the satisfactory nature of the coal specified.

C That a variation from values given in *a* and *b*, if not exceeding 5 per cent in any one of its terms, and 2 per cent in *c*, be considered as compliance.

D That producer builders adopt a plan used with success in Germany, of maintaining their own test plant, which may be used to operate their own factories, that they make preliminary trials of a coal, the use of which is contemplated by a purchaser after a provisional sale, the results, if satisfactory, to be incorporated in the final contract, the coal being defined by its trade name, mine or vein, and size. For example, "This producer, when continuously supplied with ——— lb. of Pocahontas coal per hour," will do something, with some results to be named.

QUANTITY OF COAL CONSUMED PER HOUR BY PRODUCERS AND RATE OF CHANGE OF CONSUMPTION

25 The characteristic of producers which renders it difficult to determine the coal consumption, is the thick bed of fuel within brick-lined walls, screened from observation except through small poke holes. With the usual structure it is practically impossible to judge the condition of the bed, or the condition before and after feeding a given weight of coal. The coal consumed may be equal to the coal fed, or more or less may have been consumed than was fed. In boilers a similar problem is met, but the error is minimized by long runs, making the weight of coal fed during the interval many times that resting on the grates at any one time, and so reducing the error as much as desired. A similar practice can be adopted for producers, but to reduce the error of judgment to a value as small as is acceptable in boilers the time must be greater, and in the following proportion

$$\frac{\text{(Time of run for boiler)}}{\text{(Time of run for producer)}} = \frac{\text{(Time to consume . . . . weight of coal in boiler grate)}}{\text{(Time to consume . . . weight of coal on producer bed)}}$$

so that the time of run should be greater, the slower the rate of combustion and the greater the weight in the fire.

26 There are three methods in use for determining the rate at which coal is consumed:

A From the weight of coal fired, and a judgment of the condition of the bed before and after, assisted by measurement of the height of bed and parallel removal of ashes in proportion to coal fed, as indicated by the proximate analysis of the fuel.

27 Judgment of the bed condition at the beginning may be based on the quick building of a new fire, assuming the whole to be in the condition (*a*) of fixed carbon, (*b*) original coal, (*c*) of any fraction of either, and at the end, by quenching, mixing and analysis of the mixture of green coal, partly burned coal and ashes. This method is open to many possible sources of error, as indicated by the three possible assumptions of original condition. It is difficult to obtain a uniform coal-coke-ash mixture for sampling and analysis without grinding, which is usually impracticable. In the ultimate analysis, also, the physical nature of the coal will not be shown, as soot or lampblack or fixed carbon may exist in clinkers and be charged as available carbon, whereas in these forms it is really a dead loss.

B Continuous weighing of the whole producer, when the producer is small enough, may give results of value when the run is long, but not when it is short, as it is difficult to indicate a few pounds on a scale heavy enough to weigh the thousands that may be present in iron, brick, and coal charge.

28 While this might seem to be an ideal method, it also involves a judgment of bed condition, and there is no means of telling whether a loss in weight means fixed carbon burned or volatile and moisture driven off, while a gain in weight may indicate an excess of fuel fired or merely an accumulation of ash. In any case the method must be confined to small producers and shop tests, as it cannot be applied at all to a producer erected in its final condition.

C Gas analysis may indicate a certain weight of carbon in the form of CO, and CO_2, and CH_4, from which, given the ultimate analysis of coal, there can be calculated the weight of coal that could have produced this quantity of these gases. This furnishes an indirect determination of coal consumed from gas analysis, coal analysis and quantity of gas.

29 This method is not even as exact as the two analysis and the gas quantity determination. It is difficult enough because illuminants or rich hydrocarbons and CO_2 will be more or less freely absorbed in the scrubber by the excess of water used and water vapor will be condensed, and also because the carbon in the CO_2 and CO must be assumed as coming from fixed carbon alone, from volatile alone, partly from both, or just from *C*, shown in the ultimate analysis. One of these assumptions must be made or implied before coal weight can be judged from gas analysis and quantity. Several calculations of this kind made on the report data of the United States Geological Survey producer tests failed by a considerable margin to check with the coal weighed, and on these tests greater refinement was used than is possible in ordinary commercial tests on the basis of cost.

RECOMMENDATIONS

30 It is recommended that the weight of coal be determined from the weight of coal fired with these precautions:

A Regular intervals of feeding and uniform amounts.

B Regular removal of ash, preferably in proportion to the coal fired, as indicated by the proximate analysis.

C Constantly maintained level, determined by bar with flat plate at right angles as large as will pass through top holes after leveling the fire. The use of a bar or stick, without a bearing plate extending over considerable bed surface, may lead to error, and cases have been known where a purchaser was intentionally deceived in this way.

D No measurement to begin until bed is at least eight hours old under approximately the load to be used for the run.

E Length of run to be such that the total coal regularly fired is at least equal to ten times the weight of the normal producer content, which is about equivalent to the acceptable 12-hr. run of a boiler test; in which case if an error of coal equivalent to ¼ of the bed contents were made, the error in coal consumed would be effected only about 2½ per cent.

B.T.U. EQUIVALENT OF COAL CONSUMED

31 There may be just as many values for this as combinations can be made of B.t.u. per pound of coal and weight of coal consumed, but as each part of a pound of coal consumed does not represent the same fractional part of the calorific power of the fuel, the value for the volatile weight being much greater than for the fixed carbon, and zero for the ash, it follows that a given loss of weight in the producer does not necessarily represent a heat liberation of this weight of coal.

RECOMMENDATIONS

32 It is recommended that the calorific power of coal, multiplied by the weight consumed, each modified by consideration of the difficulties pointed out, be accepted as giving the B.t.u. equivalent of coal consumed, of calorific power proportionate to the weight; with the understanding that this may not be strictly true.

QUALITY OF GAS

33 From all producers the gas passes through a wet scrubber, supplied with a quantity of water large enough to condense nearly all steam and absorb some rich hydrocarbons and carbon dioxid. The resulting gas is saturated with water vapor, and carries some water in the form of moisture or spray, together with some solid matter, perhaps tar as vapor or as liquid mist and possibly also lamp black or soot. Exact analyses of gas will then differ somewhat with the place of sampling, but in no case does the ordinary volumetric analy-

sis indicate the presence of water vapor, tar or solids. Ordinarily quality of gas is considered as defined by (*A*) volumetric analysis, (*B*) calorific power.

34 *A* Volumetric analysis by the standard apparatus will give O, CO, CO_2 H, and hydrocarbons, assumed to be CH_4, or C_2H_4, which can be separated only by more refined methods when desired. Such standard analysis is comparatively easy but, in unskilled hands, is equally likely to give wrong results. In any case the results are quite certain to vary somewhat with the place of sampling, especially when hot unscrubbed samples are compared with cool scrubbed ones.

35 *B* Calorific power of gases is always determined by burning gas in a calorimeter with continuously circulating water. It is assumed that all the gas supplied to the burner is completely burned, whereas this is not at all the case with weak gas under 100 B.t.u. per cu. ft. except with the exercise of great care and some skill in manipulation of burner and draft. The gas approaches the burner carrying more or less water vapor, and is burned in free air with the ever-present atmospheric moisture; the flue gases leaving the instrument may be reduced in temperature to anything desired, and for exact work this should equal the temperature of the air and gas supply. This implies that these have been made equal, which is not always possible. Corrections may be made approximately but never exactly, because the quantity of air is unknown, as are the moisture content, the precise instrument-radiation factor for room temperature, the air circulation and the conditions of neighboring bodies absorbing and emanating radiant heat.

36 If enough hydrogen free or combined, is present, the flue gases will escape in a saturated condition at the temperature of the water and so carry off heat enough to account for the difference between the vapor carried off by the products of combustion and that brought in by the air and the gas. This is seldom if ever corrected for. If there is only a little hydrogen, and the air dry, all of its water may be carried off in vapor with other products, leading to the impression that there was no hydrogen in the gas.

37 Such a determination of calorific power gives what is termed the high or true value. Subtracting the latent heat at 212 deg. of the water apparently produced by the combustion of hydrogen, the quantity being found by collecting the instrument drops or calculating from gas analysis, there is obtained a lesser value known as the low or effective value. This latent heat is ineffective for raising the temperature of gases during combination, and is not liberated

at all in gas engines. As a matter of fact neither is some of the sensible heat of gases and liquid water effective, so that there may be as many conceptions of the low or effective calorific value as there are assumptions made about it. It is therefore a very indefinite term, of doubtful value in commercial operation, and with a possible value only in scientific investigations of heat liberation in engine cycles. It has come into practice partly because it measures most nearly the heat actually liberated in the gas-engine cylinder in causing a pressure rise, and therefore, that which is effective in preparing for the doing of work at the expense of heat. It has also come into practice because it permits gas-engine guarantees of efficiencies to look better than when made in terms of the high value. Because of its uncertain meaning, however, it has been a source of controversy.

38 Recent investigations by a committee of the American Gas Institute show that different instruments give different values for the same gas, so that it would be best to give the name, in making commercial agreements regarding calorific power. In all cases the instrument reading, with due precautions that the final temperature are approximately equal to gas and air temperatures, without any correction whatever is sufficiently close for most commercial work and is most easily defined.

39 *C* Calorific power may be calculated by formula from volumetric analysis, but this is indirect, and should be used only as a check when direct methods are available.

RECOMMENDATIONS

40 It is recommended that quality of gas be defined by:

a Volumetric analysis near the engine by a specified standard apparatus, and by calorific value B.t.u. per cu. ft. by a specified instrument, taken when the three temperatures, air, gas and flue, differ by not more than 10 deg. fahr. between any two. The calorimeter results are to be accepted without correction.

b That the use of low value and the distinction between high and low value be avoided in commercial work.

c That the volumetric analysis be considered as an indication of the working of the producer, and a guide to its adjustment and manipulation, rather than as a measure of the good quality of the gas, except as noted in the case of hydrogen under adaptability.

d Compliance with any definition of quality or volumetric analysis be considered satisfactory when within 5 per cent of the value of any numerical quantity given.

QUANTITY OF GAS.

41 When the quantity of gas is great in large plants and the calorific power is low, as any but natural gas always is, the problem of its measurement is quite beyond the range of any commercial meter, by reason of the disproportionate cost of meter installation to the value of the information. This fact has led to the proportionate-meter design, the application of pitot and venturi tubes, and the dropping of gas holders. There are available then, these methods of measurement as well as the determination of gas quantity by chemical calculation from the weight of coal, ultimate analysis of coal and volumetric analysis of gas. Any method of measurement must be more or less protected from gas-pressure pulsations due to intermittent suction, especially where many engines synchronize in their suctions from the same main.

42 Holder-drop determinations were perhaps the first practiced, when plants began to get beyond the commercial illuminating gas-meter capacity, as practically all these plants were pressure-producer types delivering pressure gas. Because of the necessarily limited sizes of holders, some containing only five minutes' and few over fifteen minutes' full-load supply, the time of observation was likewise short, shorter than the supply time by reason of time lost in manipulating large gate valves. This involves some error due to the difficulties of measuring by a holder of large diameter dropping rapidly, the more or less bulging plates, the difficulty of averaging the temperature for the whole volume, the surging of the water seal caused by possible change of pressure, especially at the beginning and the end of run. Holders have been known to drop as much or more with the passing of a cloud on a summer's day.

43 Moreover, as the holder filled faster than the normal rate of engine consumption of gas, at the time of filling the flow of air through the producer might easily be too fast, and being succeeded by a period of no flow there would result a gas fluctuating in quality, for which adjustment of design valves cannot be made. These facts are responsible for at least some of the poor results shown by holder-drop tests, yet most of the published data of gas consumption of large engines and delivery of producers were obtained in this way.

The expense of holders is so great and their real value so little in modern systems that this method will probably not be much used in the future, as gas holders will not be installed except for small-capacity pressure regulators.

44 Manufactured direct-reading dial meters give the most positive reading and have a fairly constant error over a considerable time; but all have errors which must be determined by proving, but under the conditions of use as the error may vary with rate of flow, pressure on supply side, loss of pressure, temperature, and pressure pulsation. They are so expensive as to be commercially unavailable for any but small gas capacity systems , except where purchase of gas makes metering a necessity. Some of the larger ones, especially of the proportional type when used with dirty gas, may be very much in error, cases being known where a large meter recorded the same quantity of gas at all loads of the engine, a condition quite impossible with the engine in question. When such meters are new and form part of the permanent installation, mutual acceptance of their readings may be made a matter of agreement between the contracting parties, in which case the condition should be specifically stated.

45 Large gas flows have been fairly successfully measured by venturi meters, but the calculation of flow from the increase of velocity head can be made only when the absolute pressures of the gas flowing and the density of the gas are accurately known. The absolute pressures are determinable by barometer and water manometers; but the throat ratio must be small enough to give at least three inches of water difference in velocity head at the smallest flow to be observed, a condition that may result in a too serious permanent loss of pressure in the pipe line without a pressure booster at maximum load. Pressure fluctuations are practically of no consequence, but intermittent flow may be serious, as pulsation of the velocity-head difference may necessitate a judgment of the fair average. Cases have been known where this pulsation was so great as to make the maximum momentary reading twice the minimum. Pressure regulators, to be of assistance, must be of the gas-holder or large-tank form to equalize the flow. Determination of gas density needed for venturi and pitot calculations requires accurate gas analysis and the taking of temperatures. Installation must not be near any bends or obstructions, and means provided for cleaning the throat frequently.

46 Direct measurement of velocity head by pitot tubes has been used in some cases, but when the piping is sufficiently large to avoid

serious loss of head the velocity head is so small as to involve large errors of observation, especially when the flow is pulsating, even when delicate differential manometers are used. In any case the velocity distribution across the pipe is not uniform, requiring a search across the pipe on at least two diameters at right angles, and a calculation from the data of the mean head. This difficulty is great when the tube is near any bends or valves. To make the pitot readings greater the tube may be used in venturi throats, and its reading used to check those of the venturi meter itself. This is probably the best method known for large flows, but it requires a density determination from gas analysis.

47 Just as the coal consumption in producers may be calculated, as explained, from the ultimate analysis of coal, gas analysis and quantity of gas, so may the quantity of gas be calculated from the two analyses and a measurement of the coal consumed; but this method has so many potential errors as to be almost useless except as a check on other more direct methods.

48 In all cases, meters must be set in by-passes to permit of cleaning just before a measurement, as dirt and water may cause serious error.

RECOMMENDATIONS

49 Correct gas measurement is so difficult or costly, especially when the quantity is large, that its determination should be avoided in commercial relations whenever possible. When one party is responsible for a complete installation, no division should be made and the performance guarantee should include only the performance from producer input to engine output.

a When necessary, large gas measurements may be best made by venturi tubes checked by pitot tubes in the throat; but not too wide a range of flows should be attempted on one throat. Steps should be taken to reduce flow fluctuations to a negligible amount.

b No dial reading of a manufactured meter can be assumed to be correct, unless proved before and after the run under the same pressure, temperature and flow conditions.

c As a matter of contracting agreement, any meter reading or gas quantity determination may be mutually accepted whether correct or not. This is especially convenient when a meter is part of a permanent installation.

d Holder drop tests may be used with fair results where holders contain not less than 15 minutes' supply, if proper precautions are used and care taken to avoid serious positive and negative acceleration of gas flow through the producers.

e A quantity of gas determined by the best method available for any case may be considered as in compliance with the guarantee when not more than 5 per cent above or below guarantee.

B.T.U. EQUIVALENT TO GIVEN QUANTITY OF GAS OF DEFINED QUALITY.

50 This may be taken as the product of the B.t.u. per cu. ft. and the number of the cubic feet determination. When either is a variable its average for a given time is to be taken by the method of mean ordinates, by plotting each reading vertically to a horizontal time base, joining points by straight lines and integrating areas in the usual way.

HORSEPOWER OF ENGINES AND VARIATION IN HORSEPOWER

51 This quantity is generally the prime variable in the series of quantities fixing the general performance of the plant, in as much as all other quantities are usually specified and guaranteed, the quantities being fixed for a given horsepower output or load, or a given change of load. Considerable confusion has resulted from the possibility of various interpretations of engine horsepower and engine load, especially with respect to full load, normal load, overload, maximum load, and no load; the time an engine must run under given load to prove its ability to carry that load and its right to a rating at that load; and from uncertainty of the relations among indicated, brake, effective, and friction horsepower, one being specified or guaranteed which is not directly measurable, but which is to be determined from another that is measurable.

52 On the assumption that a purchaser buys an engine to drive something as indefinitely long as may be necessary, the time involved in proof of ability might be likewise indefinitely long. In this case a 100-h.p. engine would be one that can deliver 100 h.p. as long as supplied with fuel and properly attended. It may be reasonably assumed, however, that a gas engine, after attaining a steady state under the specified load, as indicated by jacket and exhaust tem-

peratures, is able to carry that load indefinitely, if it can do so for twelve hours. The time to reach the steady state for large engines may be taken as not less than three hours from starting, and in small engines not less than half an hour.

53 The use of the term "load" and its modifications is to be discouraged, as a survival of commercial rating, which is an arbitrary rating of horsepower capacity convenient for marking drawings and shop records of manufacture, for the cataloging and tabulation of manufacturer's data. Some horsepower is always implied and it simplifies matters considerably if the numerical value of that horsepower is expressly stated.

54 Statement of horsepower should always be in terms of brake-horsepower whether it can be directly measured or not, but when not, all assumptions made in its evaluation and the methods of indirect determination should be specified to eliminate the personal peculiarities and preferences of different test experts.

55 The speed to be used in all horsepower determinations is best taken as the total number of revolutions by mechanical counter for the entire length of test, divided by the time in minutes. This may be checked by instantaneous readings or intermittent countings taken at *regular* intervals and numerically averaged.

56 Brake-horsepower should always be directly measured when the conditions permit. Its positive nature is so desirable that it is worth considerable trouble to obtain.

57 Direct-connected generators have, when new, efficiency curves well determined, so that the manufacturer's record curve may be accepted. But this method should be then expressly stated and the curve made a part of the agreement. By this method the electrical output may be determined, but never with uncalibrated instruments, especially when alternators have been previously driven in parallel before accurate adjustment of regulation.

58 The horse-power capacity of large engines, direct-connected to pumps or compressors, may best be expressed in terms of compressor or pump indicated horsepower. When the responsibility for the engine and driven parts is divided, as it frequently is, the friction of the parts should be made a matter of preliminary agreement to arrive at each pump or compressor cylinder horsepower, and should then be eliminated from further mention.

59 Large engines, driving machinery by rope or belt transmission and so erected or constructed as to make direct brake-horsepower determination impossible, should include as a condition of the guaran-

tee of brake-horsepower a specified method of indicated horsepower and engine-friction determination to give the guaranteed brake-horsepower by difference. In no case should the difference be accepted as equal to the indicated engine horsepower at zero brake horsepower.

60 Indicated-horsepower determinations of gas engines are very unreliable, cases being known of the indicated values determined by high class experimenters being less than the directly measured brake values—quite sufficient proof of their uncertainty. It is not desirable here to enter into the causes; but in order to eliminate uncertainty and controversy there should be an agreement:

- *a* Precisely how many cards are to be taken, when and how often.
- *b* What make of indicator.
- *c* Proof of calibration of spring.
- *d* What type of reducing motion, and how connected, preferably by drawing.
- *e* How the cards shall be integrated.
- *f* How the speed to be used shall be found.

61 In all cases where there are negative card areas or complete negative cards, as in the two-cycle engine pumps, it should be understood that their work-equivalent is to be subtracted from the work-equivalent of positive areas of cards. The negative or bottom loop of four-cycle cards, when taken with high-scale springs, should be ignored as unmeasurable, except possibly at very light loads when the engine is throttle governed.

62 Engine friction, or ratio of $\frac{\text{b.h.p.}}{\text{i.h.p.}}$, may be made a matter of agreement without any contemplated measurement, from the opinions of contracting parties or by the mutual acceptance of a b.h.p.-i.h.p. curve determined from a similar engine and tested with indicators in the contemplated way with a brake or the electrical generator connected. This method is perhaps the best available, as it permits of using a shop or other good test of a similar engine, which is essentially the practice of the electric-generator manufacturers. The only other method of determination of engine friction is by taking indicated horsepower at no load and assuming it to be constant for all loads. This method is better for steam than gas engines, to which it is extremely ill-suited, as is proved by repeated checks of it against the direct measurement already referred to. Some engines at zero

b.h.p. give cards so small in area, and require at the same time so high a spring scale as to make the area useless within 10 per cent, even if constant. Cases are known where the maximum card area in a series was fully three times the minimum, even with fairly good speed regulation; moreover, the gas port friction varies with load in an unknown way.

TIME-INTERVALS

63 As the original records of guarantee fulfillment tests have a special legal significance, too much care cannot be exercised in their form, especially in the clearness of the statements of quantities and time of determination. For this reason the method of recording time and time-intervals may properly be a matter of agreement; time clocks and date stamps may be used at the time of taking each individual observation, or all readings and records may be made at the stroke of a bell and brought to the bell operator signed, for stamping just after taking.

REVOLUTIONS, PARTIAL OR COMPLETE, AND TIME INTERVAL

64 Engine speed measurements are data in

a Horsepower calculations in which for indicated horsepower there is needed the number of similar cycles executed in one minute rather than the actual speed at any one time; and for brake-horsepower direct measurements the average speed of overcoming the resistance, or the total distance that would be traversed by the point of resistance in one minute, if free: this also does not involve the real speed at any minute.

b Proof of speed regulation or ability of the engine to maintain a given value for any time interval.

65 When engines are to drive alternators in parallel, the rate of change of speed in extremely small time-intervals, down to hundred parts of a second, is important. As any part of a complete revolution, divided by the time in minutes, is just as properly the engine speed in r.p.m. as the revolutions completed in a whole hour divided by sixty, and as these two may be very different indeed in amount and constancy, even with constant load, and doubly so for sudden load change, it is evident that speed definition in terms of revolutions per minute leads to endless controversy.

66 In commercial transactions one method or instrument should be specified as a part of the agreement, making its results the definition of the term speed. In fact, several different meanings may very properly be incorporated in the same guarantee, each defined by its own instrument or method of measurement.

67 There are available a variety of possible ways of determining speed to be noted. These may be applied to the half-speed shaft of four-cycle engines, the main shaft, cam shaft or governor spindle or any other rotating part; but as these will all give different results, the place of attachment must be specified when delicate regulation is in question. The method of attachment is also important, as counters and tachometers may be gear-driven, direct-driven by pin or disc clutch or belt, or held to a punched lathe center and driven by a triangular prism with sharp edges to avoid slip, or by a rubber cone in a plain lathe center, which may slip considerably.

68 The following methods for speed determination are in use:

a Hand counter and stop-watch, counter held to lathe center for one minute, more or less, or read for one minute, more or less, without application at beginning, or removal at end of interval.

b Mechanical counter and adding machine, read at long intervals of time.

c Hand tachometer, mechanical, electrical, or hydraulic.

69 All of these tachometers give instantaneous readings, more or less lagging and seldom agreeing with the average of counters; some have permanent instrument errors varying with time of application (electric), or with a great variety of other conditions; and all involve slippage at the point of application.

d Belted, geared or direct-driven tachometers, intended to eliminate slippage at the point of application.

70 With the belted type, if the belt slips or flaps the speed fluctuations will be dampened, and the tachometer will not indicate them; while the geared type of tachometer may involve back lash. These are also made of the recording type by the addition of pencils, or pens and time-clock-driven paper. All require calibration, preferably by their makers, and their range of accuracy is limited.

e Chronograph and seconds-clock apparatus, though expensive, are by far the best for complete revolutions and not too small parts of revolutions.

f Frequency meters on alternator circuits are good speed indicators in connection with the number of poles, and in some cases no other is needed.

g Positively driven small alternators, with frequency meters, especially of the tuning fork synchronizing type, are good but expensive instantaneous speed indicators within limits.

h The use of the tuning fork to mark the time on smoked paper over a driven drum is a poor method sometimes used.

i Cross-current measurement in parallel alternator circuits is the best indication at any instant of the momentary difference in speed of the two machines. It is most easily made but requires more electrical instruments than are found on the average switchboard.

71 It seems further desirable, in accordance with the recommendations concerning the substitution of b.h.p. figures for fractional or normal loads, to stop the use of per cent variations in speed and substitute two limiting speeds. For example, instead of stating that at a constant load of 100 h.p., the engine speed will be 200 r.p.m., or more than 2 per cent above or below, the matter can be put in the form

Constant Engine Brake Horsepower:	100	50	00
Engine speed limits over 15 min., by mechanical counter attached to cam shaft,			
maximum	102	105	109
mimimum	98	99	101

Great care must be exercised after a load change, to indicate not only the mode of speed measurement but also when the measurement should begin and end.

72 The instrument should be specified, and the maker's name and the size should be given, and if important, subject to maker's calibration before and after test.

PHYSICAL OR CHEMICAL CONDITION OF COAL, NOT INCLUDED IN QUALITY BUT AFFECTING ADAPTABILITY TO THE PRODUCER

73 There are certain characteristics of coals closely related to their availability for producers and to their fulfillment of conditions not ordinarily considered as fixing their quality. These are:

a Tendency to cake and coke. This depends on temperature; whether after coking there will be left hard or soft coke;

in large or small lumps; of porous or solid character; easily gasified as fixed carbon or not; tar-free when coked or not.

b Quantity of tar set free in coking and combustion.

c Clinkering tendency, associated with fusibility of ash, or its tendency to flux with the producer brick work or other filling.

d Form of sulphur, indicating a tendency to remain in the ash and promote clinkering, or to gasify and so to corrode iron work, especially where water is encountered.

e Uniformity of size. Especially with anthracites a mixture of large and small sizes seems to pack the bed and resist blast more than a uniform size.

f Water of crystallization. Its loss may cause large lumps of lignite to break down on heating, into pieces varying from sand to gravel in size, with a tendency to pack the bed.

g State of the fixed carbon, whether easily gasified or not as certain forms approach the lampblack condition, which is practically ungasifiable in an ordinary producer.

h Nature of the volatile, whether easily split into soot or not, or whether the condensible tars can be fixed by heating.

i Strength of the lumps of original coal or its coke, measuring the tendency to crush under the weight of upper layers; especially important with peats and some briquettes.

RECOMMENDATIONS

74 As there is no known way to fix any of these characteristics, some of which are of essentially practical importance, there is need of great caution in guaranteeing the performance of any coal which has not been tried.

PHYSICAL OR CHEMICAL CONDITION OF GAS NOT INCLUDED IN QUALITY BUT AFFECTING ADAPTABILITY TO THE ENGINE

75 Just as certain physical and chemical properties characterize coal in its relation to the producer, properties yet undefinable because in an early stage of development, yet quite essential in practical operation, a similar condition exists with gases, but to a less acute degree. Some of these gas characteristics are:

a Presence of gritty solids tending to grind out bearing or rubbing surfaces.

b Presence of solids, whether gritty or not, tending to fill up openings and collect in the combustion chamber in non-conducting layers, easily becoming red hot and causing pre-ignitions.

c Presence and amount of lampblack, which, besides the tendencies under *a* and *b*, may, with oil or water, form a gum on the bearing surfaces, especially the regulating valves.

d Presence and amount of tar in vapor, liquid or mist form, and possibility of picking up from coating on piping and other parts. Tar is one of the most serious causes of disturbance of valve movement, especially sliding regulating valves, besides caking hard on the combustion chamber, where it causes preignition.

e Amount of hydrogen or illuminants, or relation of the amounts to other substances, significant in the sense that certain relative quantities may have low ignition temperatures and cause pre-ignition, the tendency toward which is different in practically every engine.

f Temperature of the gas. This affects the weight of charge to which the power of the engine is in direct proportion; so that both charge and gas must be as cool as possible.

g Pressure and fluctuations.

76 This may affect both power and efficiency of the engine, as the gas flow to the engine is proportional approximately to the square root of sum of gas pressure above atmosphere and cylinder vacuum caused by suction, while the air flow is similarly dependent on cylinder vacuum alone. Any setting of the mixing valve for correct mixture must be made for some gas pressure, and any change of pressure, however momentary, will admit more or less than the original quantity of gas, decreasing the power in both cases, and where excess enters wasting it with decreased efficiency. The importance of this fact even during one suction should be more widely recognized.

GENERAL RECOMMENDATIONS

77 All terms made in a guarantee should be defined. All guaranteed quantities must be capable of measurement, and only one acceptable mode of measurement should be specified.

78 There should be no conflicts of quantities.

79 Builders best serve their own interest, when units are in terms most satisfactory to the purchaser, and hence involve only input and output for definite fuel, horsepower and time.

80 Builders' ratings are matters of private interest to facilitate shop procedure and cataloging; they should not be used in guarantees, but may be used in describing the engine to identify it with public records.

81 Standard forms of specification and guarantee are undesirable as cumbersome and sometimes inadequate, actual conditions being seldom twice the same.

82 The legal nature of a guarantee must be kept in mind, especially as the terms and procedure involved are not matters of common knowledge; in case of controversy courts must interpret by attempts to get at accepted practice in the art through experts, in the legal sense, who may not be so in the scientific and engineering sense and may be more interested in protecting their client than in arriving at truth.

83 Capability should not be guaranteed, but only actual performance. Failure to meet a test requirement does not prove lack of capability. A given gas having repeatedly produced an m.e.p. of 80 in an engine, another similar engine is capable of 100 h.p., when its dimensions and speed with m.e.p. of 80 figure 100 h.p., even though it never did so.

84 The time element in any observation or number of observations, per result or method of averaging, should always be kept in mind. How long a run is necessary to prove the h.p., how long a count to get the r.p.m., and how often, how many tests to prove the b.t.u. per cu. ft. of gas, and how long each, are all questions to be understood by both parties.

85 Steady conditions should be established, or be expressly stated as prerequisite and not be left as implied.

86 Substantial fulfillment of some things is fulfillment, whereas literal fulfillment is necessary for others. Margins should be established and agreed upon.

87 Expense of test and conduct should be borne by the builder except when the purchaser imposes unfair requirements, in which case he should be informed of the cost and be required to bear it. This is especially important when long runs are contemplated, requiring relays of skilled observers, or when gas measurements require meters, or where the purchaser's expert tries to show how much he knows by insisting on absurd refinement or untried schemes of test invented by himself.

88 The output energy of the producers equals input energy of the engines without correction or qualification, except when some gas

generated is used for auxiliary purposes. For complete plants the guarantee should be over all performance only.

89 When complete plants are guaranteed by one party the guarantee should relate only to producer input and engine output.

90 In tests for fulfillment no other data than that required by contract conditions should be taken, with no exceptions.

91 The place and time of operation and test for fulfillment should always be expressly stated.

92 Builders should always expressly reserve the right, and sufficient time, for preliminary tests for adjustment and *take complete* advantage of the opportunity.

93 Original records, with signatures and date stamps, should be kept for all fulfillment test data and it should be expressly agreed that a copy be given to the party not in possession.

Respectfully submitted,

C. E. Lucke, *Chairman*	
Arthur West	
J. R. Bibbins	*Gas Power*
E. T. Adams	*Standardization*
James D. Andrew	*Committee*
H. F. Smith	
Louis C. Doelling	

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A.I.E.E. and A.I.M. E can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Railway Association. Statistical Bulletin No. 56, 57–A. *Chicago, Ill., 1909.*

Association of Transportation and Car Accounting Officers. Reports of committees to be presented to convention at Chattanooga, Tenn., December 14, 15, 1909.

Colloid Matter of Clay and its Measurement. (Bulletin No. 388, U. S. Geological Survey.) By H. E. Ashley. *Washington, Govt., 1909.*

Concrete. By J. C. Trautwine, Jr., and J. C. Trautwine, 3d. *New York, J. Wiley & Sons, 1909.* Gift of authors.

Contributions to Economic Geology, 1908. Pt. 1. Metals and Non-metals, except Fuels. (Bulletin No. 380, U. S. Geological Survey.) By C. W. Hayes and W. Lindgren. *Washington, Govt., 1909.*

Effect of Oxygen in Coal. (Bulletin No. 382, U. S. Geological Survey.) By D. White. *Washington, Govt., 1909.*

Expenditure of Public Money. Gift of Civic League of San Francisco.

Fauna of the Caney Shale of Oklahoma. (Bulletin No. 377, U. S. Geological Survey.) By G. H. Girty. *Washington, Govt., 1909.*

Geological Reconnaissance in Northern Idaho and Northwestern Montana. (Bulletin No. 384, U. S. Geological Survey.) By F. C. Calkins. *Washington, Govt., 1909.*

Geology and Ore Deposits of Goldfield, Nevada. (Professional Paper No. 66, U. S. Geological Survey.) By F. L. Ransome. *Washington, Govt., 1909.*

Monthly Meteorological Summary for 1907–1908. (U. S. Weather Bureau, Nome, Alaska.) Gift of Arthur Gibson.

Notes on Explosive Mine Gases and Dusts. (Bulletin No. 383, U. S. Geological Survey.) By R. T. Chamberlin. *Washington, Govt., 1909.*

Ohio Engineering Society. Report of Thirtieth Annual Meeting. *Columbus, O., 1909.* Gift of the Society.

Oscillations de Lacet des Véhicules de Chemins de Fer. By Georges Marié. *Paris, H. Dunod and E. Pinat, 1909.*

Papers on the Conservation of Mineral Resources. (Bulletin No. 394, U. S. Geological Survey.) *Washington, Govt., 1909.*

Papers on the Conservation of Water Resources. (Water Supply Paper No. 234, U. S. Geological Survey.) *Washington, Govt., 1909.*

Pre-Cambrian Geology of North America. (Bulletin No. 360, U. S. Geological Survey.) By C. R. Van Hise and C. K. Leith. *Washington, Govt., 1909.*

Providence Association of Mechanical Engineers. Constitution, By-Laws and List of Members. 1907–1908. *Pawtucket, R. I.*

Purification of Some Textile and Other Factory Wastes. (Water Supply Paper No. 235, U. S. Geological Survey.) By H. Stabler and G. H. Pratt. *Washington, Govt., 1909.*

Relations Between Local Magnetic Disturbances and the Genesis of Petroleum. (Bulletin No. 401, U. S. Geological Survey.) By G. F. Becker. *Washington, Govt., 1909.*

Rensselaer Society of Engineers. List of Members, Constitution and By-Laws, 1909. *Troy, N. Y., 1909.*

Report of the Committee on Supervision of Public Improvements and Expenditures of the Civic League of San Francisco. September 30, 1909. *1909.* Gift of Civic League.

Report on Electrolysis. By W. S. Williams. *1909.* Gift of Civic League of San Francisco.

Scaling and Corroding Substances and their Elimination from Water for Boilers. By J. C. W. Greth. (Reprint from Proceedings of Scranton Engineers Club, June 1909.) Gift of W. B. Scaife & Sons Co.

Smokeless Combustion of Coal in Boiler Plants. (Bulletin No. 373, U. S. Geological Survey.) By D. T. Randall & H. W. Weeks. *Washington, Govt., 1909.*

Structural Materials in Parts of Oregon and Washington. (Bulletin No. 387, U. S. Geological Survey.) By P. H. Darton. *Washington, Govt., 1909.*

Surface Water Supply of the United States, 1907–1908. Pt. 2. South Atlantic Coast and Eastern Gulf of Mexico. (Water Supply Paper No. 242, U. S. Geological Survey.) By M. R. Hall and R. H. Bolster. *Washington, Govt., 1909.*

Testing and Performance of Steam Generating Apparatus. By A. Bement. (Reprint from Vol. 1, Transactions, American Institute of Chemical Engineers, 1908.)

Underground Water Resources of Connecticut. (Water Supply Paper No. 232, U. S. Geological Survey.) By H. E. Gregory. *Washington, Govt., 1909.*

Yakutat Bay Region, Alaska. (Professional Paper No. 64, U. S. Geological Survey.) By R. S. Tarr and B. S. Butler. *Washington, Govt., 1909.*

EXCHANGES

Design of Submarines. By N. F. Hay. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.)

Effect of Parallel Middle Body upon Resistance. By D. W. Taylor. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.

Evolution of Screw Propulsion in the United States. By C. H. Cramp. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.)

Foreign Trade Merchant Marine of the United States: Can it be Revived? By G. W. Dickie. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.)

FUEL TESTS WITH ILLINOIS COAL, (Circular No. 3, University of Illinois Engineering Experiment Station.) By L. P. Breckenridge and Paul Diserens. *Urbana, Ill., 1908.*

INFLUENCE OF THE POSITION OF THE MIDSHIP SECTION UPON THE RESISTANCE OF SOME FORMS OF VESSELS. By H. C. Sadler. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.)

INSTITUTION OF CIVIL ENGINEERS. *Proceedings.* Vol. 177. *London, 1909*.

MANCHESTER ASSOCIATION OF ENGINEERS. *Transactions.* 1908–1909. *Manchester, 1909*

NATIONAL ELECTRIC LIGHT ASSOCIATION. Thirty-second Annual Convention. Vol. 1–3. *New York, 1909.*

NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS. *Transactions.* Vol. 25. *Newcastle-upon-Tyne, 1909.*

PRODUCER GAS BOAT MARENGING. By H. L. Aldrich. (Advance paper, Society of Naval Architects and Marine Engineers, November, 1909.)

RIVETS IN TENSION. By R. Curr. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.)

SOME SHIP-SHAPED STREAM FORMS. By Wm. McEntree. (Advance paper, Society of Naval Architects and Marine Engineers, November 1909.)

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society, and these are on file, with the names of other good men not members of the Society who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

085 Business opportunity. Exceptional offer will be made to the right man, who can promote considerable additional capital required for a growing business; one who has a record as a good business manager and can show himself competent to financier a shop. Shop located in the Central West and engaged in building high-class engine work; strictly modern plant, in operation day and night since January. Give full particulars of past experience, etc.

086 Designer. A particularly able designer of alternating current generators and motors, for a leading position in well known electrical manufacturing company near New York.

087 Superintendent for eastern boiler shop. Must be temperate, able to lay out work and to estimate; good handler of men. State experience, and salary expected.

088 First-class experienced pump designer, man with number of years experience and able to go ahead with new designs.

MEN AVAILABLE.

329 Member desires position as factory manager or mechanical engineer. Has had wide experience developing new inventions. Best references.

330 Mechanical engineer, ten years experience foundry and machine shop, construction, boiler testing and selling; office experience and drafting; four years wool manufacturing.

331 Member, at present superintendent in large machine shop, where he has been for several years, would like a change of locality; 19 years experience in manufacture of steam engines, steam turbines, and machine tools. Capable of filling first-class position.

332 Mechanical engineer, Associate Member, technical graduate, eight years experience in steel works and general office, desires position as chief engineer, superintendent or sales engineer. Familiar with all kinds of steel works machinery, construction work, and accounting; can handle men, cut down costs, and systematize general office work.

333 Superintendent and manager desires change for larger opportunity. High-grade organizer and executive. Specialized on equipment, production, and costs.

334 Mechanical and electrical engineer desires position (East preferred) as assistant to mill engineer or manager of works on the design and equipment of power plants and industrial works; age forty-three. Has had six years experience as engineer of works with two important manufacturing companies.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ABBOTT, William L. (1891), Manager, 1907–1910; Ch. Operating Engr., Commonwealth Edison Co., 139 Adams St., and *for mail*, 4616 Beacon St., Chicago, Ill.

ABORN, George P. (1889; 1892), Mgr., Geo. F. Blake Mfg. Co., East Cambridge, and *for mail*, 55 Burroughs St., Jamaica Plain, Mass.

ARNOLD, Edwin E. (1900; 1906), Metal Products Co., 226 Abbott St., Detroit, Mich.

BANTA, Earle J. (1907), Ch. Engr., Cinn. Equipment Co., Cincinnati, O.

BARRETT, Walter A. (Junior, 1906), Sales Dept., Bass Fdy. & Mch. Co., and *for mail*, 714 Woldwood Ave., Fort Wayne, Ind.

BARTON, Henry L. (1903), V. P., Metal Products Co., 226 Abbott St., Detroit, Mich.

BASINGER, James G. (1907), Civil Engr., 52 Broadway, and *for mail*, 523 W. 121st St., New York, N. Y.

BIXLER, Harry Z. (1907), Worth Bros. Co., Coatesville, Pa.

BOGARDUS, Henry A. (Associate, 1907), Henry A. Bogardus & Co., 159 W. Huron St., Chicago, Ill.

BOLLER, Alfred P., Jr. (1901), 45 E. 17th St., New York, N. Y., and East Orange, N J.

BRANCH, Joseph G. (1904), Pres., Branch Publishing Co., 46 Van Buren St., Chicago, Ill.

CARROLL, Alexander W. (1905), 524 Westminster Ave., Elizabeth, N. J.

CROOK, Geo. Louis (1905), Factory Mgr., E–M–F Co., Plant 3, Detroit, Mich.

DEAN, Arthur M. (Junior, 1907), Matheson Motor Car Co., Wilkesbarre, Pa.

FARWELL, E. S. (1899), with George F. Hardy, 309 Broadway, New York, N. Y.

FRANKENBERG, Geo. T. (Associate, 1907), Mech. Engr., Ralston Steel Car Co., East Columbus, and *far mail*, 1290 Franklin Ave., Columbus, O.

HAGERTY, Walter W. (Junior, 1905), Y. M. C. A., Pottsville, Pa.

HALE, Robt. Sever (1894; 1897; 1899), Supt., Sales Dept., Edison Elec. Ill. Co., 39 Boylston St., and *for mail*, Tennis and Racquet Club, 939 Boylston St., Boston, Mass.

HANSON, Walter S. (Associate, 1902), Pres., El Reno Alfalfa Milling Co., El Reno, Okla.

HENDEE, Edward Thomas (Associate, 1908), Mgr. Mchy. Dept., Joseph T. Ryerson & Son, and *for mail*, 4143 Sheridan Rd., Chicago, Ill.

HORNE, Harold F. (Junior, 1909), 595 West Side Ave., Jersey City, N. J.

HURLEY, Daniel (Junior, 1904), 1329 11th St., N. W., Washington, D. C.

JOHNSON, Lewis (1880), P. O. Box 447, Covington, La.

KRUESI, August H. (1901; Associate, 1904), Designing Engr. in Charge Constr. Engrg., Genl. Elec. Co., and 22 Washington Ave., Schenectady, N. Y.

KRYZANOWSKY, Constant J. (Associate, 1902), Ch. Engr., Reliance Motor Truck Co., Cor. King and Adams Sts., Owosso, Mich.

LILLIBRIDGE, Ray D. (Associate, 1907), 100 Broadway, and P. O. Box 824, New York, N. Y.

MILLER, Herman G. (1908), Mech. Engr., Rubber Regenerating Co., and *for mail*, 427 N. Calhoun St., Mishawaka, Ind.

MILLHOLLAND, William Knox (1907), Secy., Internatl. Mch. Tool. Co., and *for mail*, 3446 N. Capitol Ave., Indianapolis, Ind.

MOSS, Sanford A. (1903), Engr. Turbine Research Dept., Genl. Elec. Co., West Lynn, and 36 Sachem St., Lynn, Mass.

MOWERY, John N. (1906), Asst. M. M., Lehigh Valley R. R. Offices, Auburn, N. Y.

ORCUTT, Harry F. L. (1900), Hartford, Sutton-on-Sea, Lings, England.

PHELPS, Charles C. (Junior, 1909), Editor Steam, 114 Liberty St., New York, N. Y.

POWEL, Samuel W. (1880), Asst. Mch. Engr., Am. Radiator Co., and *for mail*, 679 Auburn Ave., Buffalo, N. Y.

RAPLEY, Frederick H. (1905), 11 Thurlow Rd., Hempstead, London, N. W., England.

SMITH, Wm. E. (Junior, 1908), Babcock & Wilcox Co., and *for mail*, 318 E. Park Ave., Barberton, O.

STEBBINS, Theodore (1903), Herrick & Stebbins, 14–16 Church St., New York, N. Y.

SYMINGTON, E. Harrison (Associate, 1903), Wks. Sales Mgr., T. H. Symington Co., Rochester, N. Y.

VALENTINE, Warren P. (Junior, 1904), Summerlea Apts., Summerlea and Elwood Sts., Pittsburg, Pa.

WATERMAN, Charles (1903), Supt., Southern Motor Wks., Jackson, Tenn.

WEINLAND, Hermon G. (Junior, 1905), Mech. Engr., Safety Emery Wheel Co., and *for mail*, 226 W. College Ave., Springfield, O.

WHITING, Richard A. (Junior, 1909), Instr. Exper. Engrg., Stevens Inst. of Tech., Hoboken, and *for mail*, Oradell, Bergen Co., N. J.

WRIGHT, Ernest N. (1890), Cons. Engr., 691 Huntington Terrace, Pasadena, Cal.

NEW MEMBERS

BRYCE, James Wares (Associate, 1909), Goss & Bryce, 76 William St., New York, N. Y.

KOENIG, Samuel L. (Junior, 1909), U. S. Engrs. Dredge, Capt. C. W. Howell, Galveston, Tex.

MEYER, C. Louis (Junior, 1909), 210 S. 36th St., Omaha, Neb.

SANGUINETTI, Philip C. (Associate, 1909), Marwick, Mitchell & Co., 79 Wall. St., New York, N. Y.

GAS POWER SECTION

CHANGES OF ADDRESS

BULMER, Wm. Carr (Affiliate, 1909), 882, Mahoning Ave., Youngstown, O.

NEW MEMBERS

BECK, M. (Affiliate, 1909), Ch. Engr., Alamo Mfg. Co., Hillsdale, Mich.

CUTLER, Frank G. (Affiliate, 1909), Steam Engr., Tenn. Coal, Iron & R. R. Co., Ensley, Tenn.

HAYWARD, Charles B. (Affiliate, 1909), Editor, The Automobile, 119 W. 25th St., New York, N. Y.

TILDSLEY, Joshua C. (Affiliate, 1909), Ch. Engr., Martin Sta., P. G. & E. Co., Bay Shore Dist., San Francisco, Cal.

WILSON, R. A. (Affiliate, 1909), Constr. Engr., Carnegie Steel Co., Ohio Wks., Youngstown, O.

STUDENT SECTION

CHANGES OF ADDRESS

HAYNES, H. Hasbrouck (Student, 1909), Stevens Inst., Hoboken, N. J.

JEHLE, Ferdinand (Student, 1909), 101 E. John St., Champaign, Ill.

KELLOGG, E. W. (Student, 1909), 1112 La Salle Ave., Chicago, Ill.

LURIE, A. N. (Student, 1909), present address unknown.

MANSFIELD, W. M (Student, 1909), 582 Jackson St., Milwaukee, Wis.

SCHUSTER, George (Student, 1909), 407 Stoughton St., Champaign, Ill.

COMING MEETINGS

December and January

Secretaries or members of societies whose meetings are of interest to engineers are invited to send in their notices for publication in this department. Such notices should be in the editor's hands by the 18th of the month preceding the meeting.

ALBERTA ASSOCIATION OF ARCHITECTS
January, annual meeting, Edmonton. Secy., H. M. Whiddington, Strathcona.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
December 27, Boston, Mass. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN FEDERATION OF TEACHERS OF MATHEMATICS
December 28, 29, annual meeting, Baltimore, Md. Secy., C. R. Mann, University of Chicago.

AMERICAN INSTITUTE OF ARCHITECTS
December 14–16, annual convention, Washington, D. C. Secy., Glenn Brown, Octagon Bldg.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
December 8–10, annual meeting, Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN SOCIETY OF CIVIL ENGINEERS
December 1–15, 220 W. 57th St., New York. Papers: The Crosstown Tunnel of the Pennsylvania Railroad, J. H. Brace and Francis Mason. The East River Tunnels of the Pennsylvania Railroad, J. H. Brace, Francis Mason, S. H. Woodard. Secy., C. W. Hunt.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
January 18–20, annual meeting, 29 W. 39th St., New York. Secy., W. M. Mackay, Box 1818.

AMERICAN SOCIETY OF HUNGARIAN ENGINEERS AND ARCHITECTS
December 4, Room 703, 29 W. 39th St., New York. Paper: High Structures in New York, Alexander Pollacsek. Secy., Zoltan de Nemeth, 907 Prospect Ave.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
December 7–10, annual meeting, 29 W. 39th St., New York. December 11, St. Louis; December 17, Boston, Mass. July 26–29, 1910, joint meeting with Institution of Mechanical Engineers, Great Britain. Secy., Calvin W. Rice, New York.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
December 28, 29, annual meeting, Ames, Ia. Secy., L. W. Chase, Univ. of Neb., Lincoln, Neb.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS
December 6, New York meeting. Secy., W. H. Ross, 154 Nassau St.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS
December 14, 15, annual meeting, New York. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

ASSOCIATION OF TRANSPORTATION AND CAR ACCOUNTING OFFICERS
December 14, 15, Chattanooga, Tenn. Secy., G. P. Conard, 24 Park Pl., New York.

BOSTON SOCIETY OF ARCHITECTS
January 4, annual meeting. Secy., E. J. Lewis, Jr., 9 Park St.

BOSTON SOCIETY OF CIVIL ENGINEERS
January 26, annual meeting, Chipman Hall, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

BROOKLYN ENGINEERS' CLUB
December 2, 117 Remsen St., Brooklyn, N. Y. Paper: Steel Sheet Piling, A. R. Archer. Secy., Joseph Strachan.

CANADIAN SOCIETY OF CIVIL ENGINEERS
Quebec Branch, January 21, annual meeting, Montreal. Secy., C. H. McLeod, 413 Dorchester St., W.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
December 21, Prince George Hotel, Toronto. Papers: Gas Manufacture, C. G. Herring. Secy., C. J. Worth, Union Sta.

CIVIL ENGINEERS SOCIETY OF ST. PAUL
January 10, annual meeting. Old State Capitol Bldg., 8 p.m. Secy., D. F. Jurgensen, 116 Winter St.

COLORADO SCIENTIFIC SOCIETY
December 18, annual meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

ENGINEERS CLUB OF ST. LOUIS
December 1, annual convention, 3817 Olive St. Secy., A. S. Langdorf, Washington University.

ENGINEERS SOCIETY OF PENNSYLVANIA
January 4, annual meeting, Harrisburg. Secy., E. R. Dasher, Gilbert Bldg.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA
January 18, annual meeting. Secy., E. K. Hiles, 803 Fulton Bldg., Pittsburg.

FRANKLIN INSTITUTE
December 10, January 28, Witherspoon Hall, Philadelphia, Pa. Lectures: A Safer America, W. H. Tolman; Road Administration and Maintenance, L. W. Page.

INDIANA ENGINEERING SOCIETY
January 14–16, annual convention, Indianapolis. Secy., Chas. Brossmann, Union Trust Bldg.

MICHIGAN ENGINEERING SOCIETY
January 12–14, annual meeting, Lansing. Secy., Alba L. Holmes, 574 Wealthy Ave., Grand Rapids.

MONTANA SOCIETY OF ENGINEERS
January 6–8, annual meeting, Butte. Secy., Clinton H. Moore

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS
January 12, annual meeting, Madison Square Garden, New York. Secy., Benjamin Briscoe, 7 E. 42d St.

NATIONAL COMMERCIAL GAS ASSOCIATION
December 12, 14, annual convention, Madison Square Garden, New York. Secy., L. S. Bigelow, Light Publishing Co., Willimantic, Conn.

NATIONAL GAS AND GASOLENE ENGINE ASSOCIATION
November 30, December 1, 2, LaSalle Hotel, Chicago, Ill. Secy., Albert Stritmatter, Cincinnati, O.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION
December 2–4, annual convention, Milwaukee, Wis. Exhibition of Trade School Work, C. R. Richards, Mem.Am.Soc.M.E. Secy., J. C. Monaghan, 20 W. 44th St., New York.

NEW ENGLAND RAILROAD CLUB
December 14, Copley Square Hotel, Boston, Mass. Paper: The Curtis Turbine Applied to Marine Propulsion, Chas. B. Edwards. Secy., Geo. H, Frazier, 10 Oliver St.

NEW ENGLAND WATER WORKS ASSOCIATION
January 12, annual meeting. Secy., Willard Kent, 715 Tremont Temple, Boston, Mass.

NEW JERSEY SANITARY ASSOCIATION
December 3, 4, annual meeting, Laurel-in-the-Pines, Lakewood. Secy., J. A. Exton, 75 Beech St., Arlington.

NOVA SCOTIA SOCIETY OF ENGINEERS
December 9, N. S. Telephone Co. Building, Hollis St., Halifax, 8.15 p.m. Paper: Improvements of the Telephone, J. H. Winfield. Secy., J. L. Allan, Provincial Engrs.' Office, Halifax.

RICHMOND RAILROAD CLUB
December 13, January 11. Lectures: Block Signals, Chas. Stephens; Terminal Freight Handling, G. H. Condict. Secy., F. O. Robinson.

ROCHESTER ENGINEERING SOCIETY
December 10, annual meeting. Secy., John F. Skinner, 54 City Hall.

SHORT LINE RAILROAD ASSOCIATION
December 14, annual meeting, New York. Secy., J. N. Drake, 60 Wall St.

WESTERN RAILROAD ASSOCIATION
January, annual meeting, Chicago. Secy., E. P. Amory, Marquette Bldg.

WESTERN SOCIETY OF ENGINEERS
December papers: The Panama Railroad, Ralph Budd; Reinforced Concrete Trestles, C. H. Cartlidge. Secy., J. H. Warder, 1735 Monadnock Bldg., Chicago.

MEETINGS TO BE HELD IN THE ENGINEERING BUILDING

Date December	Society	Secretary	Time
1	Wireless Institute	S. L. Williams	7.30
2	Blue Room Engineering Society	W. D. Sprague	8.00
4	Amer. Soc. Hungarian Engrs. and Archts.	Z. deNemeth	8.30

Date	Society	Secretary	Time
December			
7–10	The American Society Mech. Engineers	Calvin W. Rice	
9	Illuminating Engineering Society	P. S. Millar	8.00
10	American Institute Electrical Engineers	R. W. Pope	8.00
14	American Society Engrg. Contractors	D. J. Haner	7.30
16	*American Institute Electrical Engineers	R. W. Pope	8.00
17	New York Railroad Club	H. D. Vought	8.15
21	New York Telephone Society	T. H. Lawrence	8.00
22	Municipal Engineers of New York	C. D. Pollock	8.15
January			
1	Amer. Soc. Hungarian Engrs. and Archts.	Z. deNemeth	8.30
5	Wireless Institute	S. L. Williams	7.30
6	Blue Room Engineering Society	W. D. Sprague	8.00
12	American Society Engrg. Contractors	D. J. Haner	7.30
13	Illuminating Engineering Society	P. S. Millar	8.00
14	American Institute Electrical Engineers	R. W. Pope	8.00
18–20	Amer. Soc. Heatng. and Ventilatng. Engrs.	W. M. Mackay	All day
18	New York Telephone Society	T. H. Lawrence	8.00
21	New York Railroad Club	H. D. Vought	8.15
26	Municipal Engineers of New York	C. D. Pollock	8.15

* Subject to change.

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1909

On a Standard Tonnage Basis for Refrigeration

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G. T. Voorhees
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E. F. Miller

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F. R. Hutton, Honorary Secretary

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1909

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Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

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STUDENT BRANCH	AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter		C. F. Hirshfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	C. F. Gebhardt	N. J. Boughton	M. C. Shedd
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	P. H. Van Etten	H. L. Hess
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College of Oregon, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. A. Kirk	J. R. Jackson
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	H. S. Coleman	John Garver
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	AndrewHamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	W. F. Colman	S. G. Wood
Penna. State College, State College, Pa.	November 9			
Columbia University, New York	November 9			
Mass. Inst. of Tech., Boston, Mass.	November 9		Fredk. A. Dewey	
Univ. of Cincinnati, Cincinnati, O.	November 9			
Univ. of Wisconsin, Madison, Wis.	November 9			

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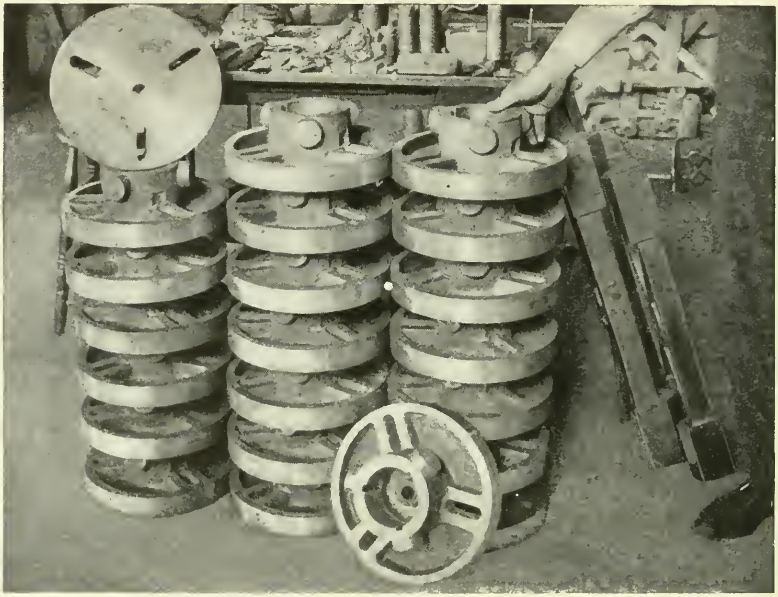
SECTION 1

Machine Shop Equipment

Machine Shop Equipment - - - - -	Section 1
Power Plant Equipment - - - - -	Section 2
Hoisting and Conveying Machinery. Power Transmission -	Section 3
Engineering Miscellany - - - - -	Section 4
Directory of Mechanical Equipment - - -	Section 5



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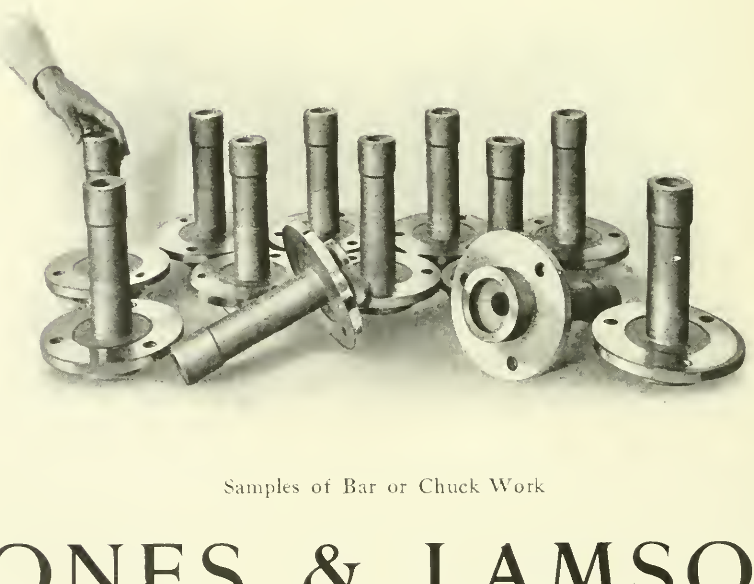

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No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No. 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

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29 West 39th Street, New York

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Power Plant Equipment

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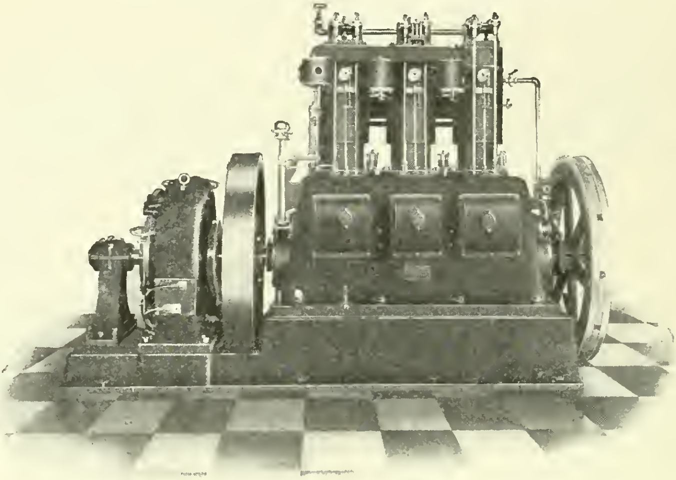

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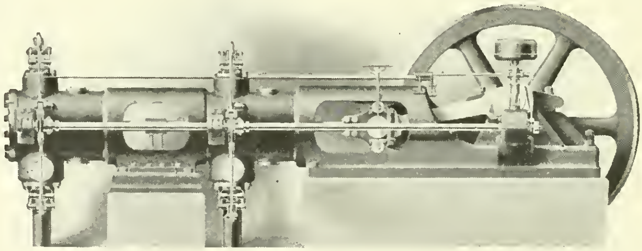

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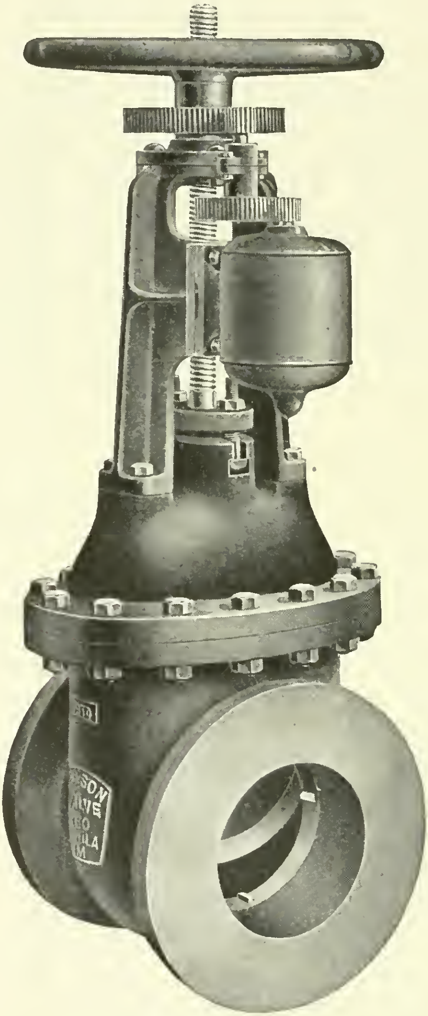

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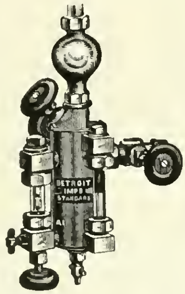

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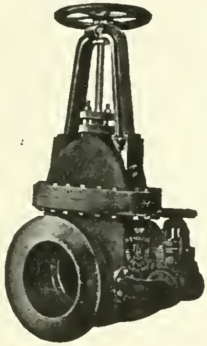

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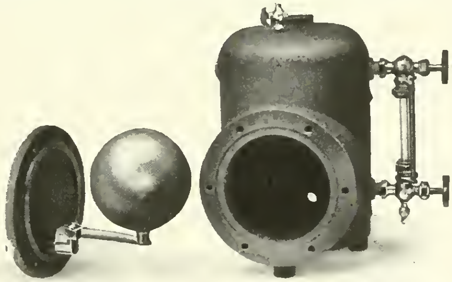

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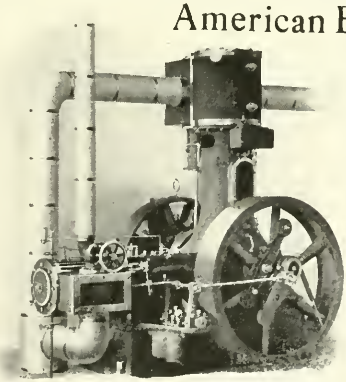

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SECTION 3

Hoisting and Conveying Machinery
Power Transmission

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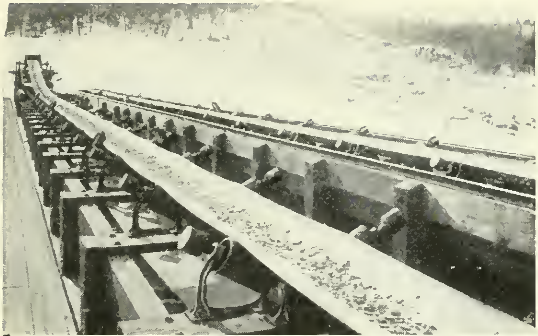
Hoisting and Conveying Machinery. Power Transmission -	Section 3
Engineering Miscellany - - - - -	Section 4
Directory of Mechanical Equipment - - -	Section 5



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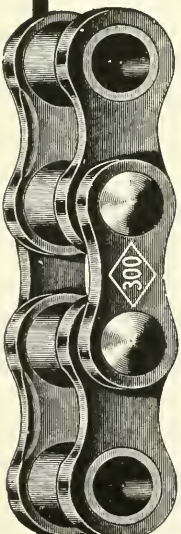

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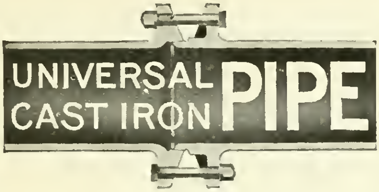
Directory of Mechanical Equipment - - -	Section 5



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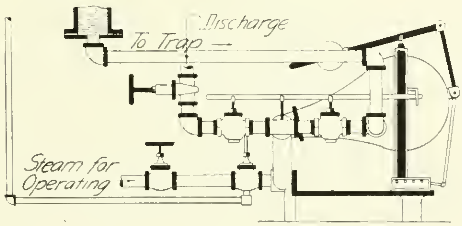

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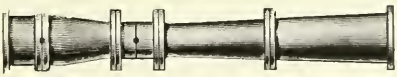

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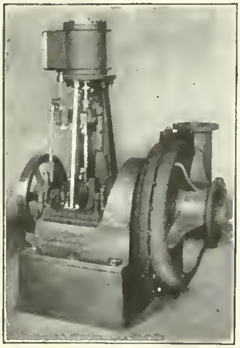

ADVERTISING SUPPLEMENT

SECTION 5

DIRECTORY

OF

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A concise reference list of Machine Shop, Power Plant and Foundry Equipment; Pumping Machinery; Power Transmission Machinery; Electrical Apparatus; Hoisting and Conveying Machinery and allied lines.

Machine Shop Equipment - - - - -	Section 1
Power Plant Equipment - - - - -	Section 2
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Engineering Miscellany - - - - -	Section 4
Directory of Mechanical Equipment - - -	Section 5

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